INSTREAM PROTECTED USES, OUTSTANDING CHARACTERISTICS, AND RESOURCES OF THE SOUHEGAN RIVER AND PROPOSED PROTECTIVE FLOW MEASURES FOR FLOW DEPENDENT RESOURCES

FINAL REPORT

SEPTEMBER 2004

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Final Report

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R-19952.000

September 2004

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1.0 INTRODUCTION AND PURPOSE

The primary objective of this effort is to establish a comprehensive list of flow dependent Instream Protected Uses, Outstanding Characteristics and Resources (IPUOCR) entities for the designated reach of the Souhegan River and to propose methods for assessing their flow dependence. Based on their seasonal flow requirements, these IPUOCR entities will serve as guideposts for designating protected instream flows. The IPUOCR evaluated included the list developed by the Department (NHDES 2004) as a starting point augmented by literature searches, stakeholder consultation and a field visit. Such information included but was not limited to designated river nomination reports, river corridor management plans, natural resources studies, natural heritage inventories and environmental assessments and impact statements. A preliminary draft IPUOCR list was created in June 2004. The preliminary draft IPUOCR list and supporting information was refined following review and comment by DES and the advisory committee and is the basis for the discussion of resources in this final IPUOCR report. In this report, the development of the final IPUOCR list is described. The final IPUOCR list was divided into flow dependent and non-flow dependent entities. Protected flows will not be assessed for the non-flow dependent entities. Approaches for establishing protected instream flows (PISF) for flow dependent IPUOCR are presented in Section 3.1. Non-flow dependent entities are identified in Section 3.2.

2.0 METHODS OF ASSESSMENT

2.1 OVERVIEW OF ALL POTENTIAL IPUOCRS

The New Hampshire Department of Environmental Services (DES) has defined the categories of Instream Public Uses, Outstanding Characteristics, and Resources (IPUOCR) that must be evaluated and included in the development of a PISF Study and eventual Water Management Plan (WMP). Categories of potential IPUOCR include the following:

Navigation: The use of the river for non-recreational, transportation purposes.

Recreation: Use of the river for swimming, boating or significant shoreland recreation such as hiking, camping, picnicking and bird watching.

Fishing: both Recreational Use and Commercial Use

Storage: Natural or man-made attributes of a river for water storage.

Conservation/Open Space**:** Issues concerning management of open space, conservation easements or municipal, state or federal parks.

Maintenance and Enhancement of Aquatic and Fish Life*:* Those aquatic-dependent species that make up a balanced, integrated and adaptive community of organisms having a species composition, diversity and functional organization comparable to that of similar natural habitats of a region.

Fish and Wildlife Habitat: Species that rely on flow and flow to regions which are important to the survival of fish and wildlife populations, including but not limited to: spawning and feeding beds, waterfowl breeding or wintering areas, freshwater wetlands or riparian habitat.

Rare, Threatened or Endangered (RTE): fish, wildlife, vegetation or natural/ecological communities: As listed by New Hampshire Natural Heritage Inventory (NHI) and nomination papers.

Water Quality Protection/Public Health: Characteristics that maintain water quality of the river including, but not limited to, chemical and physical parameters that support designated and existing uses.

Public Water Supply: An existing source of public drinking water as defined in Env-Ws 302.02.

Pollution Abatement**:** Wastewater treatment facilities or industrial treatment facilities and aspects of flow affecting assumptions of flow for dilution and dispersal of waste in mixing zones and the river's overall capacity to mitigate natural and non-point source contamination.

Aesthetic Beauty/Scenic: Including but not limited to designated viewing areas, scenic vistas and overlooks.

Hydroelectric Energy Production: An existing hydroelectric facility or a former hydroelectric facility site that has been unused for fewer than six years.

Cultural: On-going river corridor management planning effort or other local efforts to protect or manage the river, riverside parks or other public areas, or community support for riverfront revitalization.

Historical or Archaeological: Based on the presence or absence of known historical or archaeological resources.

Community Significance: A natural, managed, cultural or recreational resource or use thereof associated with the river that is recognized by local residents or a municipal document as being important to the community adjacent to the river.

Hydrological/Geological*:* A national, regional, state or local resource as determined by the state geologist or as listed in a national or state resource assessment.

Agricultural**:** As defined by RSA 21:34a.

2.2 DRAFT LIST OF IPUOCR ENTITIES

From the universe of potential IPUOCR, the project team developed in June 2004 a draft list that included IPUOCR that were confirmed to be present along the designated reach or suspected to be present. Natural history and location information was reviewed for each IPUOCR entity, and compared to initial criteria for assigning an IPUOCR plant or wildlife species or natural community or other entity to a flow-dependency category. The criteria were:

Flow-Dependent – Species with one or more life stages requiring shallow standing/flowing water within banks of river channel during summer; or a community that provides habitat for such species as an important function were included in this category. Other entities such as canoeing and kayaking and hydropower were included in this category if they were determined to be reliant on flow.

Potentially Flow-Dependent – Entities with an unclear link to flow were included in this category as well as entities with known flow dependence but unknown or unconfirmed presence in the designated reach. A determination of flow dependence was made for these entities after further literature review and the site visit.

Non Flow-Dependent – Entities in this category met none of the above criteria. The life cycles of species or activities associated with the entities in this category were not dependent on water flow or levels within river channels or floodplain at any time of the year. These entities do not depend on flow.

The draft list was delivered to NHDES on June 21, 2004 and subsequently distributed within the NHDES and to the technical review committee (TRC) and the Water Management Planning Area Advisory Committee (WMPAAC). There were few comments received on the draft list therefore the draft list and observations from the site visit formed the basis for the final list of IPUOCR for the designated reach of the Souhegan River. One comment on the draft list concerned agricultural land in Milford. This is discussed further in Section 3.

2.3 LITERATURE REVIEW

Numerous sources of information describing the resources of the Souhegan River have been reviewed including a nomination report (SRN 1999), watershed study (NRPC 1995), and water monitoring data (NHDES 2001). Other available information reviewed included NRCS soil maps, National Wetland Inventory maps, geologic resource maps, GRANIT GIS layers and aerial photos.

The review of available information was structured to develop the information base necessary to prepare a preliminary list of IPUOCR entities for the designated reach and to annotate each entity on the basis of river location and dependence on flow conditions. This preliminary list was confirmed to the extent possible and supplemented, where necessary, through consultation with state and local government and the field survey.

2.4 CONSULTATION

Agencies and organizations contacted by NAI or the NHDES included groups such as Souhegan Technical Review Committee and Water Management Area Advisory Committee members, New Hampshire Natural Heritage, Nashua Regional Planning Commission, Souhegan River Watershed Association, New Hampshire Fish and Game and the relevant conservation commissions. New information from these groups was added to the GIS database and used to describe the IPUOCR entities.

2.5 FIELD SURVEY

An on-stream survey was conducted June 28-30, 2004 to verify the existence and occurrence of the IPUOCR entities. The purpose of the instream habitat and aquatic fauna survey of the Souhegan River was to identify stretches within the river with unique hydro-morphological characteristics (HM) and instream public uses, outstanding characteristics and resources (IPUOCRs). This 3 day field survey of the entire designated reach included stops at specific prescreened locations to document the presence of each entity or the presence of conditions or habitat suitable for each entity. Candidate locations for field verification were determined from data compiled by NHDES, GRANIT layers, New Hampshire Natural Heritage data and information obtained from watershed groups. The intent was to ensure that examples of critical locations of flow dependent or potentially flow dependent resources were visited. The field crew was split into two teams. One team led by University of Massachusetts, evaluated instream habitat and aquatic fauna within the stream channel while a second team led by Normandeau Associates and University of New Hampshire evaluated riparian and upland resources.

The riparian and upland survey was guided by a set of maps which presented the available geographic information on the critical resources of the designated reach along with points to be visited. At each stop, the resources on the map were confirmed and photo documented according to the NHDES photo documentation procedures. The photos were geo-referenced using GPS and added as a layer to the GIS database. Occurrences of resources not represented in the existing database were documented. Locations along the designated reach upstream of the Route 122 Bridge in Amherst were visited on foot or by vehicle. The reach from Route 122 to the Turkey Hill Road Bridge was canoed. The reach from the Turkey Hill Road Bridge to the Merrimack River was visited on foot or by vehicle.

Typical resources encountered are presented in Figures 2.1 and 2.2. (These figures are also included on a CD attached to this report.). To begin the survey, the Souhegan River was entered at a known location, and followed either upstream or downstream. Locations were found by use of a global positioning system (GPS), which located the team's position upon the orthophotographs. If locations were easily identified by the characteristics of the river or surrounding areas, or the GPS was not available due to satellite coverage or canopy density, then locations were determined visually using landmarks then locations were transferred to maps. As each section of river was traversed, the characteristics of the river were observed and recorded digitally on handheld computers.

The equipment needed per team to perform the survey included a Hewlett Packard IPaq loaded with ESRI's ArcPad software, and ortho-photographs covering the Souhegan River and surrounding area. ArcPad was loaded with forms for entering hydro-morphologic data to be associated with the orthophotographs and sections of the river. A field notebook was used in collecting notes on each section, entrenchment, embeddedness, as well as velocity and depth percentages. A waterproof digital camera, used in conjunction with the standard operating procedure set by the New Hampshire Department of Environmental Services, was used to take photographs of some sections and points of interest along the river. A thermometer gun was used to take the surface temperature of much of the river. A canoe was used for navigating portions of the river too deep or inefficient to cover on foot. Using this equipment, the survey employed the following methods.

The characteristics considered in each river section to identify HM included the flow pattern, the substrate, surrounding banks and vegetation, canopy cover and the hydraulic patterns of the river. When the river had made an obvious change in characteristics, then the river was divided at that point, and the section traversed was mapped. In mapping, a polygon was created covering the section of the river on the ortho-photos in ArcPad, and an accompanying form was filled out for the hydro-morphologic characteristics of that section. Once the data had been collected, each successive section upstream or downstream was mapped. Each section was numbered for identification. Mapping of the river around impoundments depended upon the size and influence each dam on the river's form. The river was mapped with the exception of larger impoundments created by dams. The polygons created in ArcPad were downloaded at the end of each day so the river could be considered and analyzed as a whole. In ArcMap, the sections were all included to form the study area of the river, and the results of the habitat management unit (HMU) data could then be analyzed.

2.6 DELINEATIONS OF SECTIONS AND REACHES

Once sections were merged in the data set, we performed a thorough analysis of collected data, aerial photographs as well as IPOUCR information. Subsequently, the river was divided into nine distinct reaches which generalized the 73 sections into which it was originally divided. The reaches were determined according to similar characteristics, particularly determined overall by the HMU's distribution, gradient, and substrate but also the level of human induced alterations. In these reaches, similar habitats and species could be assumed to be potentially present.

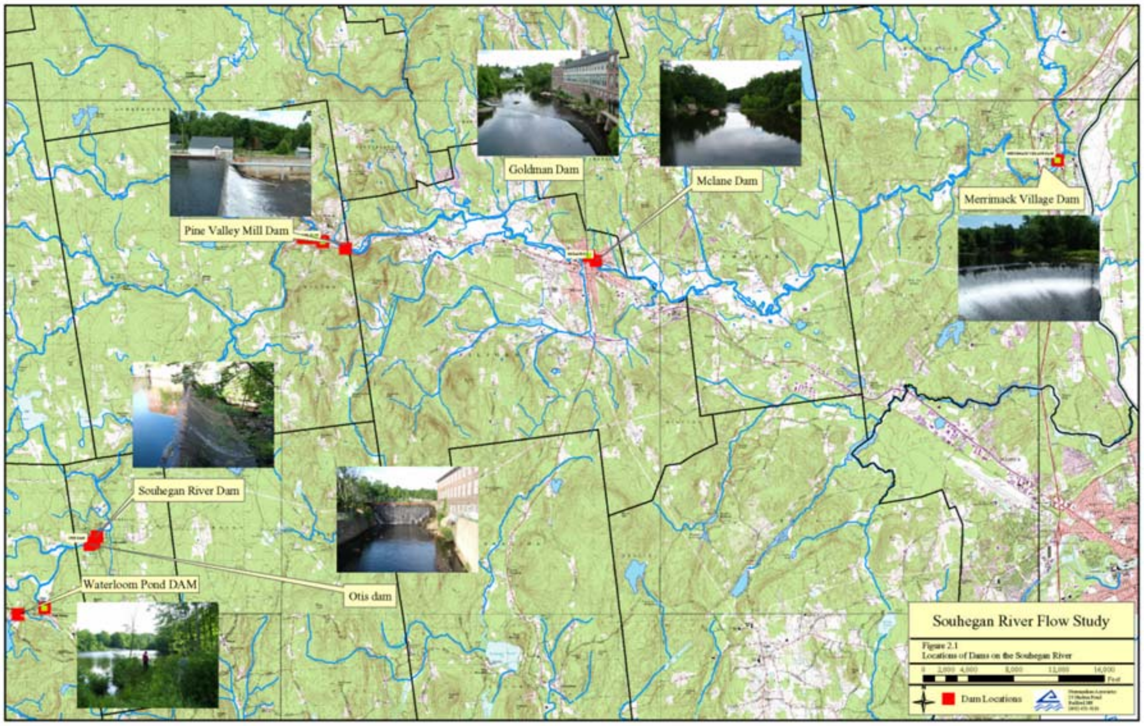


Figure 2.1 IPUOCR entities in the designated reach of the Souhegan River.

Figure 2.2 Dams along the designated reach of the Souhegan River.

Figure 2.2 Dams along the designated reach of the Souhegan River.

11 x 17

A hierarchical cluster analysis was performed using statistical software, which gathered similar sections within a reach according to their characteristics. Integrating the results of cluster analysis with expert opinion we identified 11 representative sites. These eleven sites cover about 7 miles of the Souhegan River and are the focus of the following survey in which the HMU's and IPUOCR will be surveyed for their influence upon the instream flow and habitat for fish and wildlife.

One impoundment will be also selected as a representative site of the other impoundments in the designated reach. The selection of an impoundment will be performed at a later time.

2.7 SCREENING METHODS

The IPUOCR list contained in the draft was augmented with a literature review and observations from the field reconnaissance survey. The revised list was then split into two categories based on the dependence of the entity on stream flow. These categories were flow dependent which included resources with specific well established flow requirements and non flow dependent. Potentially flow dependent resources from the draft list were assigned to either flow dependent or non-flow dependent categories.

The non-flow dependent IPUOCR are discussed below but are not expected to be addressed further in this study. The flow dependent resources are also discussed below along with proposed methods of assessment to be used to establish a protective instream flow (PISF) for each resource requiring an acceptable minimum flow. Resources requiring flows other than acceptable minimums (appropriate average or floods flows for example) are also discussed. A flowchart describing the screening process for flow dependent resources is provided in Figure 2.1.

2.8 FLOW DEPENDENCE AND CRITICAL FLOW RELATED CHARACTERISTICS OF IPUOCR ENTITIES

The list of IPUOCR entities for the Souhegan River is extensive. However, many of these entities are not flow dependent. The matrix presented in Table 2.1 contains information from the preliminary list, literature review and the reconnaissance site visit. All IPUOCR entities were then classified as either flow dependent or non-flow dependent based on information known to the project team to date. Categories in the matrix include: the resource; the reason for inclusion; the local, regional and national importance of the resource; and the flow requirement of the resource including seasonality and duration, if known. Critical Flow categories of "High", "Average", "Low" were assigned to IPUOCR if they were believed to be most sensitive to deviations from the Natural Flow Paradigm at high, average, or low flows during flow-dependent life stages or operations. Flow deviations could include change in frequency, timing, duration and/or magnitude. For example, Fowler's Toad eggs and larvae are potentially harmed by drops in summer low flows, as stranding and drying could occur, while changes in the magnitude and duration of high, low, or average flows (that exceed the Natural Flow Paradigm) could alter emergent wetland functions and species associations.

The specific locations of resources that are rare, threatened or endangered were reviewed to the extent they were available but they are not presented. Likewise infrastructure information (dams, POTWs, water supplies) that could be used in a destructive manner was reviewed but is not presented. The NHDES will make the ultimate decision on whether or not to publish these data. The matrix of IPUOCR entities provides essential information needed to screen candidate methods for the determination of protected instream flow. The IPUOCR entities were initially screened for flow dependence (Figure 2.3). If an IPUOCR entity was determined to be dependent on an acceptable

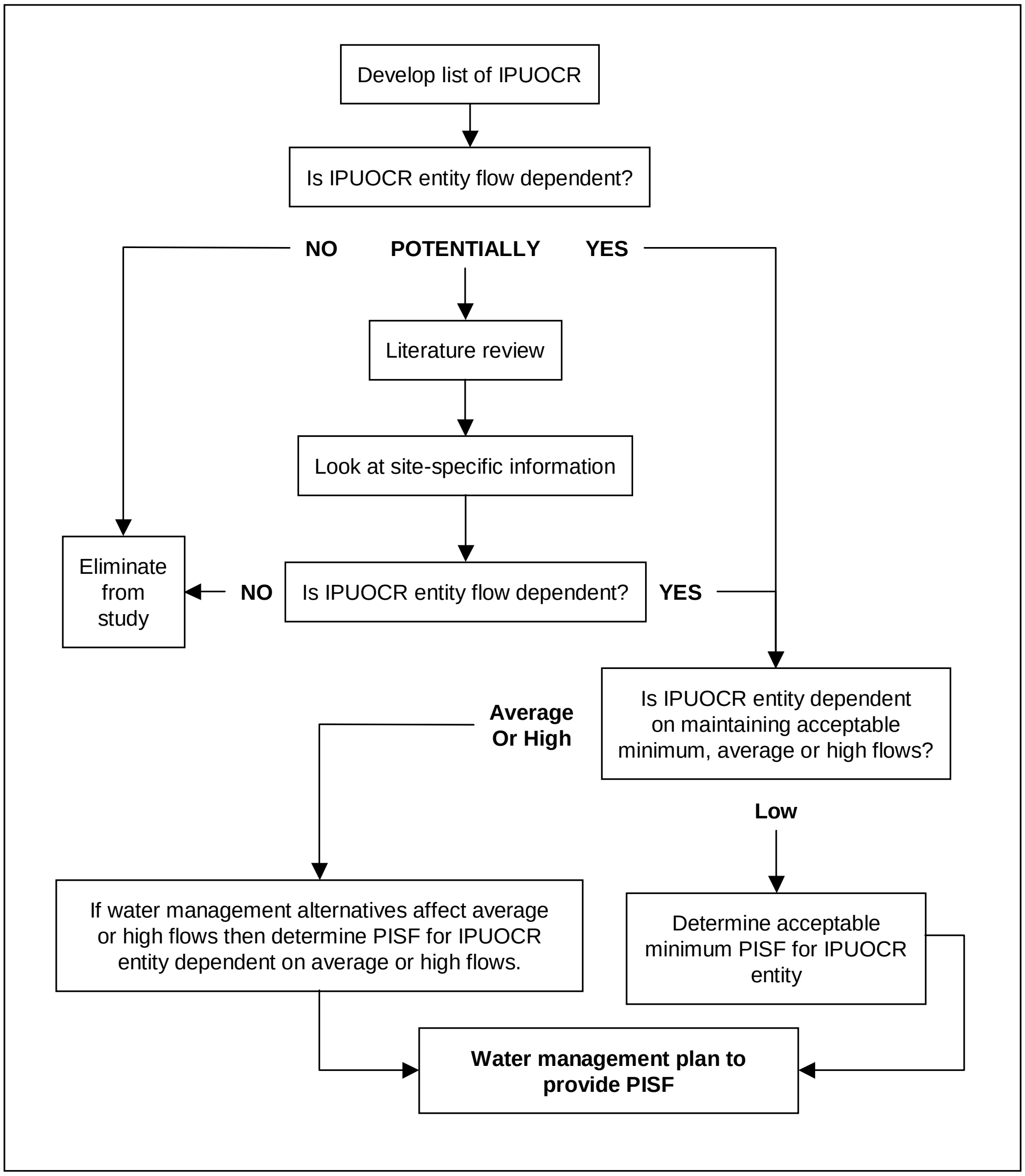


Figure 2.3. Flow chart of IPUOCR screening process.

Table 2.1. Matrix of IPUOCRS including flow dependence, reason for inclusion, critical seasons, life stages and method of assessment.

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Recreation	Boating		Yes	High, Ave		Sp, F	Determine flow needs through observation and boater interviews
Storage	SOUHEGAN RIVER DAM - New Ipswich	NEW IPSWICH	No				
	WATERLOOM POND DAM-New Ipswich	NEW IPSWICH	No				
	OTIS DAM-Greenville	GREENVILLE	No				
	SOUHEGAN RIVER DAM-Wilton	WILTON	No				
	SOUHEGAN RIVER III DAM	GREENVILLE	No				
	SOUHEGAN RIVER	GREENVILLE	No				
	SOUHEGAN RIVER III DAM	WILTON	No				
	SOUHEGAN RIVER DAM	WILTON	No				
	PINE VALLEY MILL DAM	WILTON	No				
	GOLDMAN DAM	MILFORD	No				
	MCLANE DAM	MILFORD	No				
	MERRIMACK VILLAGE DAM	MERRIMACK	No				
Fishing			Yes	Low	Adults	Su	mesohabsim
Conservation/ Open Space			No				

(continued)

Table 2.1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Aquatic and Fish Life Maintenance and Enhancement	Native Fish		Yes	All	All		Mesohabsim
	Introduced Fish		Yes	All	All		Mesohabsim
Fish and Wildlife Habitat	Fish Life-stage Habitats		Yes	All	All	All	Mesohabsim
	Mussels		Yes	All	All		Mesohabsim
	Insects		Yes	All	All		Mesohabsim
RTE Fish, Wildlife, Vegetation or Natural/ Ecological Communities	Banded Sunfish		Yes	All	unknown	unknown	Mesohabsim
	Fowler's Toad	Milford, Amherst	Yes	Low	Eggs, Larvae	Su	Floodplain Transect/Seasonal Water Level Assessment
	Pied-billed Grebe	Amherst	Yes	All	Eggs, Nest., Ad.	Sp, Su	Link to Floodplain Transect Model
	Long's Bitter Cress	Greenville	Yes	Low	All	Su	Floodplain Transect/Seasonal Water Level Assessment
	Emergent Wetlands	Greenville, Amherst, Merrimack	Yes	All	All	Su	Floodplain Transect/Seasonal Water Level Assessment

(continued)

Table 2.1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
RTE Fish, Wildlife, Vegetation or Natural/ Ecological Communities	Wood Turtle	Amherst, Merrimack	Yes	Low	Adult	W	Floodplain Transect/Seasonal Water Level Assessment
	Osprey	Milford	Yes	Low, Avg	Adult	Sp, Su, F	Link to Fish Model
	Common Loon	Amherst	Yes	Low, Avg	Adult	Sp, Su, F	Link to Fish Model
	S. New Eng. High Energy Riverbank Community	Greenville, Wilton	Yes	High, Avg	All	W, Sp	Floodplain Transect/Seasonal Water Level Assessment
	S. New Eng. Floodplain Forest Comm.	Merrimack, Amherst	Yes	High, Avg	All	Sp	Floodplain Transect/Seasonal Water Level Assess.
	Wild Garlic	Merrimack	Yes	High, Avg	All	Sp	Link to Floodplain Transect/Seasonal Water Level Assessment
	Eastern Hognose Snake	Amherst, Merrimack	No				
	Grasshopper Sparrow	Amherst, Merrimack	No				
	Giant Rhododendron	Greenville, Milford, Wilton	No				
	Siberian Chives	Merrimack	No				
	Birds Foot Aster	Merrimack	No				
	Skydrop Aster	Merrimack	No				
	Goat's Rue	Merrimack	No				
	Stiff Tick Trefoil	Merrimack	No				

(continued)

Table 2.1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Water Quality Prot./Public Health			No				review volunteer and NHDES monitoring data
Public Water Supply	Pennichuck Water Works		Yes	Low			Task 2 hydrogeo investigation
	Milford Town Wells	Amherst	Yes	Low			Task 2 hydrogeo investigation
Pollution Abatement	Greenville WWTF (wastewater),		Yes	Low		Su	review permits and NHDES holdings
	Souhegan Wood products (non-contact cooling waters)		Yes	Low		Su	review permits and NHDES holdings
	Hitchiner Manufacturing (non-contact cooling waters),		Yes	Low		Su	review permits and NHDES holdings
	Milford WWTF (wastewater)		Yes	Low		Su	review permits and NHDES holdings
	Harcros Chemicals (non-contact cooling waters).		Yes	Low		Su	review permits and NHDES holdings
	Savage Well Superfund site		No				
	Fletcher Paint Superfund site		No				
Aesthetic Beauty/Scenic			No				

(continued)

Table 2.1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Hydroelectric Energy Production	Waterloom Pond Dam	New Ipswich	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	Otis Dam	Greenville	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	Souhegan River III Dam	Greenville	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	Souhegan River Dam	Greenville	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	Souhegan River III Dam	Wilton	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	Pine Valley Mill	Wilton	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
	McLane Dam	Milford	Yes	Low?, Ave		Sp, Su, F W	interview dam owner
Cultural			No				
Historical or Archaeological			No				
Community Significance			No				
Environmental/ Fish Habitat	River Morphology		Yes	High		Sp, F	Ecomorphological Assessment

minimum flow, a procedure to determine an acceptable minimum PISF was proposed (Section 3). If an IPUOCR entity was determined to be dependent on an acceptable average or high flow, an additional step will occur. The universe of potential and practical water management alternatives will be determined for the Souhegan. If any of these alternatives affect average or high flows, a PISF will be determined for those IPUOCR entities dependent on average or high flows.

3.0 DISCUSSION OF IPUOCR ENTITIES AND PISF METHODS

3.1 FLOW DEPENDENT IPUOCRS

This section includes all flow dependent IPUOCR entities of the Souhegan River under their IPUOCR classifications as presented in Table 2.1. The discussion includes information describing the IPUOCR entities followed by the proposed method for determining protected flows for each type classification. The flow needs for each IPUOCR will be determined as described below and compiled. This compilation will provide the basis for the target flow regime to be provided by alternatives considered in the water management plan.

3.1.1 Recreation

Boating: Western sections of the river (from Greenville to Wilton) provide whitewater canoeing and kayaking during spring and periods of high water. The Wilton to Milford stretch provides limited opportunities for canoeing and kayaking because water is generally low and requires portage around dams. Below the Rt.122 bridge the river is flat and provides excellent opportunities for family canoeing. The stretch below Seaverns Bridge is impassable to watercraft because of Wildcat Falls. The river is impassable to motorboats except in western reaches, on the impoundments (SRN 1999).

Much of the river is considered passable only at high flow levels, according to the AMC River Guide (AMC 2002), with the exception of the reach from the Turkey Hill Bridge to the Merrimack which is listed as passable in medium flows. The river is apparently not considered to be runable in a canoe or kayak under low flows although the project team did navigate the section from Route 122 to Turkey Hill Bridge on June 29, 2004 with some walking through the rapids sections. The flow on that day was between 67 and 77 cfs at the USGS gage above Wildcat Falls in Merrimack which would be considered low to moderate flow. Boating flows will be evaluated qualitatively through a combination of the observations of the field teams and interviews of boaters on the river during various river stages. These stages will include low summer flows (primarily in Amherst and Merrimack sections) and high spring flows. The team will coordinate with local paddling groups to develop a consistent interview format and to target appropriate time and flow windows for both kayakers and canoeists. If any water management alternatives considered in the water management plan include substantial changes in average or peak flows, this IPUOCR entity may need to be evaluated more quantitatively.

3.1.2 Fishing

The majority of the fishing in the river is for stocked trout. The Souhegan River is regularly scheduled for stocking, and their stocking schedule can be found on the New Hampshire Fish and Game website. The species stocked in the river for 2003 were Brown Trout, Eastern Brook Trout and Rainbow Trout (see Table 3.1). The Souhegan River is a popular river for recreational fishing, as it is easily accessible, and provides a variety of habitats.

Table 3.1 Fish Stocked in Souhegan River in 2003.

Total Fish Stocked in Souhegan River - 2003				
Town	**Species**	**Age of Fish**	**# of Fish**	**Lbs. of Fish**
Amherst	BT	1+yr	945	390
Amherst	EBT	1+yr	645	268
Amherst	RT	1+yr	670	670
Greenville	BT	1+yr	945	390
Greenville	EBT	1+yr	730	329
Greenville	RT	1+yr	310	310
Merrimack	BT	1+yr	400	168
Milford	BT	1+yr	995	411
Milford	EBT	1+yr	625	260
Milford	RT	1+yr	970	970
New Ipswich	EBT	1+yr	600	272
New Ipswich	RT	1+yr	200	200
Wilton	BT	1+yr	945	389
Wilton	EBT	1+yr	690	290
Wilton	RT	1+yr	590	590

BT – Brown Trout EBT – Eastern Brown Trout RT – Rainbow Trout

3.1.3 Aquatic and Fish Life Maintenance and Enhancement

Resident Native Fish Community

We are in the process of defining a resident native fish community for the Souhegan River. Our strategy is to divide the Souhegan River into two separate fish communities. The two communities will produce an

upper reach and a lower reach with the line of demarcation taking place in Milford, where a distinct change in river morphology is observed. A third community might be considered between Wilton and Milford. Upon completion of this task, target headwater and base level fish communities will be generated. Tables 3.2 and 3.3 present the historic abundance of fish captured in Souhegan River and tributaries. The data were provided by the New Hampshire Department of Environmental Services and the Massachusetts Department of Fish and Wildlife.

Methods for achieving this goal include the selection of quality comparable rivers that are representative of both the upper and lower sections of the Souhegan River. Our representative rivers must possess physical similarities to the Souhegan and have sufficient historical data before target communities can be derived. At this time, due to a lack of historical fishing data our objectives cannot be completed, but is planned for the near future.

Native Fish Species

Species present in Souhegan River include American Eel, Atlantic Salmon, Blacknose Dace, Brook Trout, Brown Bullhead, Chain Pickerel, Common Shiner, Common White Sucker, Creek Chub Sucker, Fallfish,

Table 3.2. Breakdown of Species by Tributary and Incorporated into Single Chart for the Souhegan River

Souhegan River		
Species	**Number of Fish**	**Percent of Total Fish**
Longnose dace	231	28.88
Blacknose dace	212	26.50
Common shiner	148	18.50
Common white sucker	79	9.88
Fallfish	73	9.13
Atlantic salmon (stocked)	31	3.88
Golden shiner	10	1.25
Yellow perch	4	0.50
Brown bullhead	3	0.38
American eel	3	0.38
Redbreasted sunfish	2	0.25
Rainbow trout	2	0.25
Pumkinseed sunfish	1	0.13
Brown trout	1	0.13
Total	800	100

Purgatory Brook		
Species	**Number of Fish**	**Percent of Total Fish**
Common shiner	98	37.98
Blacknose dace	81	31.40
Common white sucker	76	29.46
Longnose dace	3	1.16
Total	258	100

McQuade Brook		
Species	**Number of Fish**	**Percent of Total Fish**
Banded sun fish	3	37.50
Eastern chain pickerel	3	37.50
American eel	1	12.50
Yellow bullhead	1	12.50
Total	8	100

South Branch Souhegan River Ashby		
Species	**Number of Fish**	**Percent of Total Fish**
Fallfish	44	26.51
Brown bullhead	44	26.51
Creek chubsucker	30	18.07
Common white sucker	25	15.06
Pumpkinseed	11	6.63
Yellow bullhead	4	2.41
Brown trout	2	1.20
Chain pickerel	2	1.20
Largemouth bass	2	1.20
Brook trout	1	0.60
American eel	1	0.60
Total	166	100

Baboosic Brook		
Species	**Number of Fish**	**Percent of Total Fish**
Longnose dace	15	18.75
Silvery minnow	13	16.25
Blacknose dace	11	13.75
Brown bullhead	6	7.50
Margined madtom	6	7.50
Longnose sucker	5	6.25
Tessellated darter	5	6.25
Common shiner	5	6.25
American eel	3	3.75
Fallfish	3	3.75
Bluegill	2	2.50
Black crappie	2	2.50
Creek chubsucker	2	2.50
Yellow perch	1	1.25
Brown trout	1	1.25
Total	80	100

Table 3.2.(continued)

Riddle Brook		
Species	**Number of Fish**	**Percent of Total Fish**
American eel	1	20.00
Eastern chain pickerel	2	40.00
Bluegill	1	20.00
Golden shiner	1	20.00
Total	5	100

Table 3.3. Spawning timeline for the Souhegan River.

	Month											
Species	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Atlantic Salmon										■	■	
Blacknose Dace					■	■						
Brook Trout										■	■	
Brown Trout												
Common Shiner					■	■	■					
Creek Chubsucker												
Golden Shiner						■	■	■				
Longnose Sucker				■	■							
Margined Madtom						■	■					
Rainbow Trout			■	■	■							
Smallmouth Bass					■	■						
Yellow Bullhead					■	■						

Golden Shiner, Longnose Dace, Longnose Sucker, Pumpkinseed, Redbreast Sunfish, Spottail Shiner, Yellow Perch (SRWR 1997).

Introduced Fish Species

Species present in Souhegan River include Brown Trout, Largemouth Bass, Smallmouth Bass, Margined Madtom, Yellow Bullhead, and Rainbow Trout. Although these species are not native, they have been introduced and are part of the aquatic community (SRWR 1997).

3.1.4 Fish and Wildlife Habitat

The Souhegan River is a Salmon Restoration river. The river is integral to the extremely successful US Fish and Wildlife Service (FWS) Adopt-a-salmon family project that uses a watershed approach for environmental education. At present, the river is the main release site for the program that currently involves approximately 25 schools in Massachusetts and New Hampshire. The river contains Atlantic salmon nursery habitat (gravelly, sloping bottoms, water temperatures, oxygen levels, and food sources), identified by FWS as the best nursery habitat in the region. The river is part of the Merrimack River anadromous fish restoration program and is considered one of the most productive rivers in the watershed (SRN 1999).

Fish Life-stage Habitats

Fish use habitat for spawning, feeding, nursing grounds, migration, and shelter, but most single habitats do not meet all of the needs of a fish. Fish change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its characteristics and functions, are important to a diversity of fish species, and their changing life history needs. Descriptions of fish species, their characteristics, and habitats may be found in Appendix A.

Macroinvertebrates

Biomonitoring surveys conducted by NH-DES appear to show that the Souhegan exhibits the macroinvertebrate faunal characteristics of a healthy riverine system. Data from these surveys is available on the internet at http://des.nh.gov/rivers/instream/souhegan.asp?link=reference . Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), (EPT taxa) are diversely represented in the Souhegan River system. These taxa are generally considered to be clean-water organisms, so their presence tends to be correlated with good water quality and stream flow. Other macroinvertebrates such as freshwater mussels and Odonates (dragonflies and damselflies) are also often dependent upon good water quality, and thus their presence can be an indicator of a healthy water body. As with most macro-invertebrates, not much is presently known about their habitat needs. It is likely that habitat used by these animals can differ from fish habitat. Therefore the investigation including macroinvertebrates would help to represent a broader range of biodiversity in making instream flow recommendations. Surveying for these species would provide greater insight into understanding how water flow, substrate, and water quality provide habitat for certain species and have potential for other species. However due to limited resources and the experimental character of such a study, we propose to focus the investigation on mussels and odonates. This makes sense from a conservation viewpoint, because both of these groups contain state and federally listed endangered species, and thus efforts to conserve habitat for these taxa generally will result in protection for imperiled ones. For reference purposes we have summarized the key biological information about freshwater mussels and dragon/damselflies.

Mussels

The freshwater mussel (Bivalvia: Unionidae) assemblage in North America is one of the most diverse known, and also one of the most imperiled (Vaughn and Hakenkamp 2001; Strayer *et al.* 2004). Essentially sedentary or slow-moving animals, the lotic species are particularly vulnerable to fluctuations in water level and current. Although many features of the watershed landscape have been shown to affect the composition of mussel communities (Arbuckle and Downing 2002), impoundment of rivers and the resultant effects on flow regime and host fish species are considered the primary factors in the decline of many North American freshwater mussel communities (Vaughn and Taylor 1999; Parmalee and Polhemus 2004; McGregor and Garner 2004). Flow stability and substrate composition determines where mussels are found in a water body (McRae *et al.* 2004), and patchiness in distribution may be due to the use of flow refuges (Strayer 1999). Flow rates that are too high can negatively affect mussels by causing reduced juvenile recruitment (Hardison and Layzer 2001).Conversely, flow rates that are too low can result in sedimentation changing the substrate type and making it unsuitable for a given mussel species. Flow management is an important factor in maintaining a healthy invertebrate community in riverine systems (Brunke *et al.* 2001).

There are 12 species of freshwater mussels found in the northeast. A concise list of species can be obtained from the Connecticut Department of Environmental Protection. These species are important in bodies of water as they maintain clean water by filtering algae and plankton, and are eaten by many species of wildlife. The species with potential to be present in the Souhegan River include Eastern Pearlshell, Triangle Floater, Brook Floater, Creeper, Eastern Elliptio, Eastern Floater, Alewife Floater, Eastern Pondmussel, Tidewater Mucket, Yellow Lampmussel, and Eastern Lampmussel.

The life cycle of mussels starts with the release of sperm into the water by a male mussel, which a female mussel collects when siphoning water for food. The sperm is retained upon her gills, where her eggs are fertilized and the eggs develop in a few weeks. The next generation of mussels emerges after this time-period as glochidia, the larvae of mussels. Fish play a host, as the glochidia attach to the gills of specific fish species. These host species of fish are attracted to the area through a chemical emission, or lure, which the female mussel produces. Using the host fish as a means of dispersal, the glochidia are capable of reaching new locations in which they can reproduce to start new populations once they mature. These mussel larvae disengage from the host fish after a period of time, and if they relocate onto suitable substrate and the flow of the river is appropriate, the immature mussel will develop, and continue the life cycle.

Most freshwater mussels live burrowed in sand and gravel substrates, often occurring in the shallows of rivers and streams. Many species prefer a habitat that offers highly oxygenated water and moderate current. Only a few species have adapted to life in lacustrine zones such as lakes, ponds, and reservoirs. Mussels play an important role in river ecology. Their filtering ability makes them natural water purifiers. They are an integral part of the food web as a food source for raccoons and muskrats. Mussels also depend on many different fish species as a means of dispersal. Some of the identified hosts include tesselated darters, blacknose dace, golden shiner, longnose dace, margined madtom, pumpkinseed, slimy sculpin and yellow perch. Mussels are good indicators of water quality. Factors such as water pollution, siltation, and impoundments have been known to cause declines in mussel populations. Well-established, diverse mussel colonies generally indicate a healthy aquatic environment.

Many of the species of mussels found in the northeast are considered threatened, or of special concern to the states in New England. Only one species, the Dwarf Wedgemussel, is considered endangered in the state of New Hampshire. As it is listed nationally as endangered, however it has not historically been reported from the Souhegan River.

Insects

There are a variety of insects which are dependant upon a river system for habitat and breeding grounds. In this study besides EPT taxa, dragonflies and damselflies are of most concern. These insects are in the order Odonata. Due to resource limitations, only Odonates will be evaluated. Other taxa will be archived for future evaluation. There are many different species of dragonflies and damselflies, and many have been located in Hillsborough County, the county in which much of the Souhegan River and its watershed is found. Dragonflies and damselflies are good indicators of water quality and are identifiable by their shed exoskeletons and adult forms. If water is impacted through sedimentation, an increase or decrease in stream flow or other drastic event, these insects are affected, as their presence depends upon high quality water. The flow needs of these macroinvertebrates varies through the season, as they emerge from rivers spring through early fall (Lenz 1997).

As of January 2003 there were 108 species of dragonflies and 44 species of damselflies in the State of New Hampshire (NH Odonates Club 2004). Currently, the only dragonfly species listed as endangered in the state of New Hampshire is the Ringed Bog Haunter *(Williamsonia linteri.)* Odonates occur around most types of fresh water, but are uncommon in fast moving sections of streams. Both dragonflies and damselflies seem to thrive near sluggish waters. As a family, Odonates require a diversity of substrates upon which their eggs are laid. Several characteristics of these organisms make them useful indicators of water quality: many are sensitive to physical and chemical changes in their habitat, many live in the water for periods exceeding one year, they cannot easily escape pollution as some fish can. Odonata are easily collected in many streams and rivers for research.

Biological summary of order (Odonata)

A. Life History

1. Eggs - usually several hundred to several thousand; either in water or in plants; usually hatch in several days to 1 month
2. Nymphal Stage (immature stage) - nymphs; usually almost 1 year (ranges from 3 weeks to 5 years)
3. Adults
   A. Most species live 40 to 50 days
   B. Crawl out of water to molt
4. Number of generations per year - most univoltine (some semivoltine or merovoltine)
5. Time of emergence - most spring and summer (some early fall)
6. Delays in development – during periods of adverse abiotic conditions diapause in the egg stage may commence for periods up to 7 months.

B. Habitat and Habits

1. Adults - many disperse widely but return to spend most of adult life near preferred aquatic habitat (not necessarily their natal habitat); some fly almost all of the time, others perch for short periods between flights
2. Nymphs - dragonflies common in slow-moving flowing waters and standing waters; not many damselflies found in flowing waters; nymphs move rather slowly, if at all; lie in soft sediment or climb about in vegetation or plant debris

C. Food

1. Adults
    - A. Capture insects with spines on front legs
    - B. Large eyes, 360 degrees to capture prey

2. Nymphs - capture invertebrates (anything they can subdue) with hinged labium

D. Respiration of Immature Stages

Closed tracheal system with gills at end of abdomen; external in damselflies, internal in dragonflies

E. Behavior

Adults - male dragonflies defend territories; unique copulatory loop; some males remain with females during oviposition

F. Significance

Important source of food for many fish species. Odonates are also important predators of mosquitoes and other biting flies associated with aquatic habitats.

Proposed Assessment Methods for Instream Resources

Literature Consulted for Souhegan River Fish Habitat and PISF

For this survey, a number of literature sources were consulted to provide insight into methods for surveying the Souhegan River. Each of the writings discusses methods of surveying flowing water, and eventually modeling its outcome. One source is a paper entitled "Overseas approaches to setting River Flow Objectives" by M. J. Dunbar et al. from the Environmental Agency and the Institute of Hydrology from the United Kingdom. Another source is "A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers", by R. E. Tharme of the Freshwater Research Institute at the University of Cape Town, South Africa. A third source consulted is "Instream Flows for Riverine Resource Stewardship", by the Instream Flow Council. The fourth literature cited is "State-of-the-art in data sampling, modeling analysis and application of river habitat modeling," a Cost Action 626 Report written by Atle Harby et al. Each approach, as described by this literature is individually determined, however, there is a definitive theme, which can be taken from their research, particularly concerning the assessment methods

A report by Dunbar et. al. identified three types of methods applied world-wide for the purpose of setting PISF.

"Look up" or standard-setting techniques, based upon simple hydrological indices such as percentage of the natural mean flow or an exceedance percentile on a natural flow duration curve are the most commonly applied. They generally aim to determine some sort of minimum ecological discharge, sometimes with seasonal considerations, sometimes with other thresholds (desirable, optimum). "Such methods require considerable resources to set up initially; but once developed require a relatively low level of resources per site. These standards can play an important monitoring and strategic role and provide interim objectives, where further investigation is justified. Good examples of look-up techniques include the "Tennant and Texas" method, and the "Basque" method.

The other set of methods is called "Discussion-based approaches and hydrological analysis**".** These methods use "structured consideration of expert opinion". "The methods are able to consider broad ecological functioning, plus species requirements at an intermediate level of detail. They may include elements such as hydraulic modeling, but the key assessment is undertaken at an expert panel workshop. This would be of particular use for setting more specific interim flow objectives, especially in the absence of clear species-related management targets, and ensuring effective targeting of further study."

The third category is "Biological response modeling", which refers to the Instream Flow Incremental Methodology (IFIM), and variations. "This type of approach is considered the most resource-intensive and defensible. Some countries have incorporated elements of the holistic approaches into their IFIM-equivalent framework. Another common approach is to incorporate multivariate classification of river sector types and their biotic communities."

The IFIM uses habitat simulation models as a basis for an integrative decision making process. It is frequently misunderstood and falsely considered equivalent to the Physical Habitat Simulation model (PHABSIM), which was the first modeling technique used for IFIM. Over the last twenty years, the models have been applied at numerous sites and improved. There has been substantial debate regarding the validity of the models (for a review see Gore and Nestler, 1988). Since the elaboration of the original PHABSIM habitat modeling software (Bovee, 1982) there have been a number of important developments (see Parasiewicz and Dunbar, 2001).

The other two sources "A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers", by Tharme and "Instream Flows for Riverine Resource Stewardship", by the Instream Flow Council provide similar perspective. They both identify standard setting approaches and concur with the notion that these methods are adequate only for reconnaissance-level studies. Both sources also identify modeling techniques as effort intensive but precise techniques that are applicable for negotiations and detailed resource use planning. As a third category, Tharme identifies holistic methods that are in some sense similar to Dunbar et. al.'s discussion based techniques, however at higher level of sophistication. In Annear et. al the third category is named "Monitoring and Diagnostic Methods that Assess the Conditions". Those however are considered a tool of adaptive management.

"State-of-the-art in data sampling, modeling analysis and application of river habitat modeling," is a report which has been created by the European Aquatic Modeling Network. The paper includes case studies from a variety of countries, and many examples of methods and equipment used to develop these surveys. This paper focuses on modeling techniques incorporating a wide scope of riverine habitat modeling that includes other taxonomic groups like pollution monitoring, etc.

One of the key conclusions is that identification of appropriate scales is a crucial element of instream habitat modeling. The authors emphasize the importance of a multi-scale approach to assessment to assure that analysis can be performed at the scales corresponding with the way biota utilize their environment and to allow for more comprehensive management. The report also states that frequently habitat assessment at some scales can be considered inefficient.

Scales can range from microscopic to macroscopic. At a microscopic scale, which deals with samples, it is ineffective to assume that a sample taken from one location could yield the same results over the entire area, which the sample is meant to represent. Two areas with similar characteristics could contain entirely different species on the microscopic scale. On the other hand, at a macroscopic scale, for example the entire river, shows that the function and species diversity is determined by the stability of the system. The problem with this scale is lack of the precision necessary for resource use decision-making.

"Mesohabitat scales are becoming more popular worldwide, and increasingly recognized as adequate scales for fish. Most commonly the size of mesohabitats correspond with the size of hydro-morphologic units, such as entire pools, riffles, runs or backwaters, They create a "functional habitat" pattern, identifiable for the entire river and allow the creation of a basis for multi-scale assessment" (Harby et al. 2004).

In summary, the following can be concluded from our literature review.

The four cited publications describe their individual assessments on research of instream methods but have a common conclusion. The methods outlined in the literature indicate differences between approaches, ranging from surveys to creating entirely new data including expert panels and utilizing available data. However, each of these four publications has separate groupings of methods, as well as a desire to create a homogenous method, which is applicable over a wide spectrum.

In addition to the desire for a unified method, most papers discussed the development of IFIM and PHABSIM, with MesoHABSIM becoming the latest, and most intriguing method discussed at this time. MesoHABSIM is an incremental method, as it is relatively easy to apply, and would deliver appropriate results. MesoHABSIM integrates the ideas of IFIM and PHABSIM, while studying rivers at a functional scale, which can be studied at a small scale, or included in a trend to create an overall model of the river. This method identifies the species and the influences affecting individual sections of the river, or hydro-morphological units (HMU's). Once each section of the river has been specifically cataloged, then an average inclusion can be made to consider the influences on species within these areas of similar characteristics. These areas can then be modeled, and the effects of outside influences can be determined with a management plan developed to determine the best situation possible for species within that reach.

Selected Methods for Fish Habitat Modeling

Our approach is to develop criteria for a flow regime that protects aquatic and riparian life. Thorough understanding of biological flow needs should create a basis for a Water Management Plan . Methods for accomplishing this task are numerous and vary greatly in their appropriateness to specific situations. Intensive analysis of techniques leads to the conclusion that physical habitat simulations provide the most desirable base and such approaches have the greatest potential for broad application on the Souhegan River.

Physical habitat models link a small number of hydraulic (depth, velocity) and habitat variables (cover, substrate) to models of suitability for target biota (habitat suitability criteria) and are useful for establishing criteria when a specific site or sites have high importance to an IPUOCR. The most common method has been physical habitat modeling using PHABSIM techniques and software, or analogous procedures (e.g., RHABSIM or EVHA). However, these techniques are limited in their resolution and applicability when extrapolated to many river miles.

MesoHABSIM modifies the data acquisition technique and analytical approach of earlier efforts by changing the scale of resolution from micro- to meso- scales, providing a mechanism that allows the assessment of habitat changes at the watershed scale. When applying the MesoHABSIM survey approach, mesohabitats (e.g. riffles, runs, and pools) are mapped at different flows along many miles of a river. The suitability of each mesohabitat for a target fish community is assessed using field surveys, and field data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure (Figure 3.1).

We propose to apply this method to all free flowing sections of the Souhegan River. In addition, we propose to perform a reconnaissance level survey in one of the impoundments. The purpose of the latter survey is to identify the species that utilize impoundment habitats and roughly estimate the value of this habitat for the aquatic community.

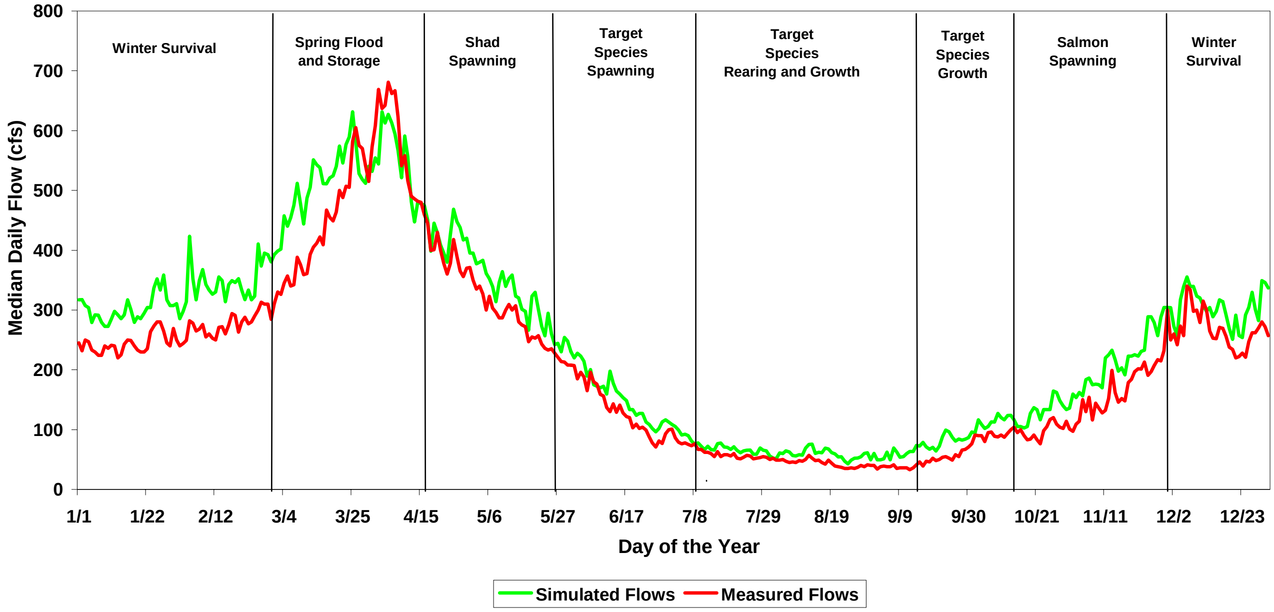


Figure 3.1. Bio-periods developed for the Quinebaug River plotted over simulated and observed hydrograph habitat suitabilities that were calculated by the physical habitat model. This plot allows determination of the accuracy of the model created using the habitat selection criteria from multiple rivers.

To create a habitat model, it is necessary to have two types of data. The characteristics of the stream and biological response functions, (habitat use criteria) allow us to evaluate Hydro-morphology in terms of habitat suitably. Because of our experience working in the Northeast, we already have a well-developed habitat database on adult and early life stages of resident native fish for regional river systems (Quinebaug River, Mill River, Fort River, Manhan River, Pomperaug River, Fenton River, Stony Clove Creek, etc.) collected from instream surveys. These data allow for the development of habitat use criteria for the majority of fish species identified in this IPUOCR report. We propose to use these criteria as a basis for evaluation of habitat quality for these species in the areas mapped with MesoHABSIM technique.

We propose to select the resident species to be modeled using the Target Fish Community approach as well as literature information on seasonal habitat needs of species present in Souhegan River. The species or species groups that have highest flow needs in particular season (eg. spawning salmon in the fall) will be selected as indicators for PISF needs and for habitat modeling. For species that are not included in our database, we will develop habitat selection criteria using literature values.

In general terms we will follow the approach developed during the Quinebaug River study (Parasiewicz and Goettel 2004) as described in the following paragraphs.

The flow requirements of the fauna and of the flow regime itself vary through the course of a calendar year. When attempting to prescribe flows in a regulated river, it is necessary to take into consideration these flow and habitat fluctuations. To do this, we partitioned the calendar into seasons. These bio-periods reflect the special or critical times that a particular fauna or life stage may be particularly limited due to a lack in habitat.

The timing and duration of bio-periods are primarily based on upon species present and life history information found in the literature. During the Quinebaug River study we made refinements to the seasons using the simulated hydrograph as a guide, primarily lengthening or shortening the period by a small percentage in order to have the biological requirements coincide with a consistent flow pattern, which is often associated with a particular bio-activity (such as high spring flows for spawning).

If biological data were unavailable or too sparse, we then developed periods based solely on consistent patterns (either relatively stable or relatively dynamic) in the simulated hydrograph. For example, the termination of the resident species' spawning period was adjusted slightly from general literature information to coincide with the inflection point of the receding limb of the hydrograph – the point where it is likely that the target fauna would cease spawning.

Spring/fall spawning and low flow summer survival/rearing and growth conditions were considered the primary biological periods of importance based on professional experience. Over-winter survival and the spring flood/storage periods are the other bio-periods and were evaluated solely by the simulated hydrograph since data for the targeted fauna are extremely sparse for these two periods.

We selected the spawning periods of the top five target resident species and those of the two selected extirpated anadromous species (Atlantic salmon and American shad) from published studies and literature sources, most of which provided data from outside the immediate Quinebaug area. Bio-period values for a given species were established by exercising professional judgment if the data obtainable were not from the Quinebaug region. For example, spawning data for fallfish was obtained (in part) from New York and Virginia sources in order to estimate the period of spawning for Connecticut and Massachusetts. If the data was limited to these two sources, we "interpolated" between the ranges of dates and consulted the hydrograph to select a season for the Quinebaug region. Figure 3.1 represents bio-periods identified for Quinebaug River.

Because of zoo-geographic proximity of Quinebaug and Souhegan River the number and type of bio-periods selected for Souhegan River should not differ from those identified for Quinebaug River, However, it is conceivable that the timing and species driving habitat criteria for each season could be modified. These details (including selection of modeled resident species) can be determined only after establishing the Target Fish Community and reference hydrographs for the Souhegan River.

To verify data from our habitat database we propose to include an instream community survey using underwater observation and electrofishing in the areas previously mapped during the habitat survey. In the shallow upstream section of the river we will collect fish with the use of 6 m^2, pre-exposed electrofishing grids. We plan to gather data on approximately 200 locations within the representative sites. In the lower portion of the river we propose to use underwater observations and record fish in various HMU's.

We also propose to collect data describing habitat use by mussels and macro-invertebrates that will allow us to create an experimental model for these creatures. Based on a preliminary habitat survey (see below) we will select a number of HMU's that will represent a wide range of habitat conditions. In seven random locations within these units we will place 0.25m^2 quadrates and sample macro invertebrates (using a submerged drift net) and mussels, which will be identified and released where they were found. These quadrats will first be swept for non-bivalve invertebrates, and then will be searched for mussels. Mussel specimens will be identified and left in situ, while non-bivalve invertebrates will be preserved in ethanol for later processing by NH DES. A goal of approximately 300 quadrat samples equally divided across the representative HMU's will be set for the Souhegan river study. These data will be valuable in a number of ways, as they will provide quantitative knowledge about the habitat preference and distribution of freshwater mussels and other invertebrates, while also expanding the functionality of the computer simulation MesoHABSIM.

The physical habitat parameters at every quadrate will be recorded as a micro-scale attributes. Due to the limited mobility of these creatures, to define habitat suitability at the mesoscale we will not collect physical habitat characteristics at the time of the survey, but rather use the range of circumstances across the range of investigated flows occurring at these locations. The appropriate data will be extracted from habitat surveys described in the following sections.

We propose to conduct mesohabitat mapping collecting from three study flows in the range between 0.15 cfsm and 2 cfsm as the primary approach to describing flow related habitat changes. The survey will be conducted at representative sites covering approximately 7 miles of river. We will collect the same data as during the reconnaissance survey, however with a much higher level of precision.

The collected data will be integrated into a GIS database and habitat quality in the sites will be evaluated using criteria established as described above. We will compute habitat flow rating curves for every hydro-morphologic unit and generalize the curves to reach level according to the proportion of the units in the reach (Figure 3.2).

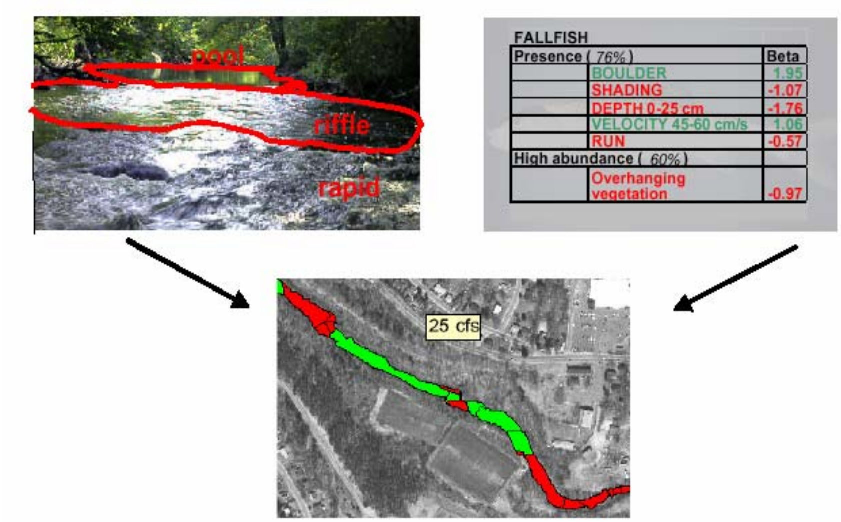


Figure 3.2. The habitat survey delineates hydromorphologic units and their physical attributes (top left). The fish survey identifies key habitat attributes affecting fish (top right). The model calculates the probability of fish presence in each habitat and delineates areas of suitable and unsuitable habitat.

Using habitat rating curves in conjunction with flow time series for each river segment or IPUOCR site, we will create a time series of baseline habitat conditions which will be analyzed for flow levels critical to the protected use. We will apply continuous under threshold habitat duration curves (CUT-curves) using the technique described by Capra et al. (1995). The process is illustrated in Figure 3.3. Using this method, we identify four habitat levels that correspond with different protection thresholds. These levels divide the flow regime characteristics along a gradient of potential impact and are named *absolute minimum, trigger, critical, and typical*.

Again we will build here upon the methodology developed during the Quinebaug River Study:

> A single set of CUT curves for a bioperiod are generated by analyzing negative run-time length (i.e. continuous durations of under threshold) characteristics of habitat time series (habitographs). Habitographs are computed by applying flow/habitat-rating curves developed for restored river conditions to a given season's flow time series. The magnitude and duration of habitat run-length characteristics relative to a series of thresholds is plotted as habitat duration curves on one chart. Thresholds are initially selected on an iterative basis until we were able to refine our evaluation to target threshold "regions". These target threshold "regions" demonstrated characteristics where trends depicting common and not-so-common occurrences could be discerned.

For the low-flow conditions, we identified four habitat levels that corresponded with different levels of thresholds. These levels were named absolute minimum, minimum, critical, and typical. To define the absolute minimum (which is the lowest habitat level allowable), we select the lowest non-zero habitat level that occurred in the pre-development daily streamflow time series. To define the other three levels, we interpret the shape of the CUT curves and their location on the graph shown below as Figure 3.4.

In Figure 3.4, the selected increment between habitat levels is 2% of the channel's wetted area. The horizontal distance between the curves indicates the change in frequency of events associated with a habitat increase to the next level. The curve spacing increases constantly but in non-uniform increments thereby displaying a sudden shift in frequency. We assume that thresholds are associated with such a significant increase of spacing between the CUT curves.

We observed that for minimum levels, which are exceeded very frequently and over long periods of time, the curves are steep and located in the lower left-hand corner of the graph. The curve representing the highest level of this group of curves has been chosen as a minimum habitat level. The first curve that stands out is identified as the critical (yellow curve) as it marks the lowest of events more common than minimum (red curve). After exceeding the critical level, the lines begin to space out a little more. The next significant increase of the distances between the CUT-curves marks a first typical (green curve) event.

For each of these thresholds, we also identified significant changes in the shape of the curves as to define the shortest common, longest common and catastrophic durations. We divided the duration of events into one of two categories: *acute* or *catastrophic*. The shortest common duration, the lowest inflection point on the CUT curve, is then used to determine the release pulse length. The longest common duration, the uppermost inflection point of the CUT curve, defined the maximum durations for which the habitat can fall under the threshold or duration between successive pulses as needed. The catastrophic length demarcates the duration that, if exceeded (e.g. for lack of water), would require

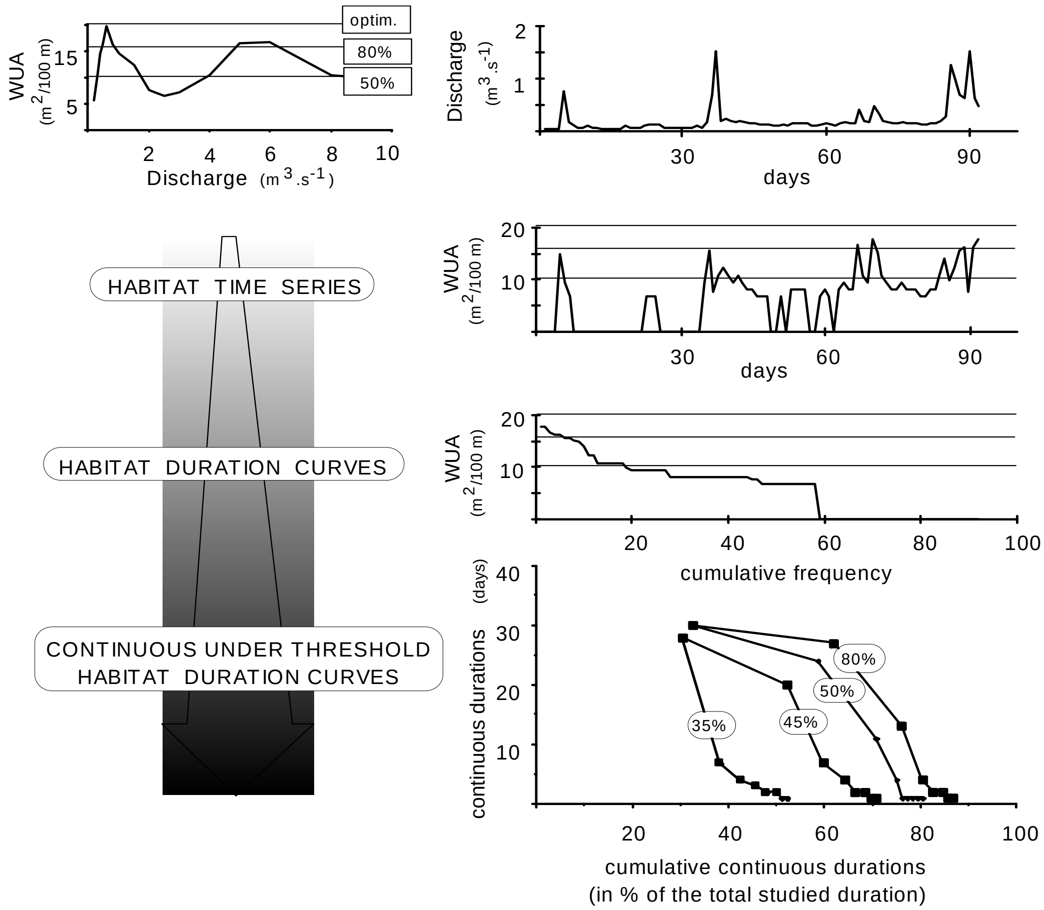


Figure 3.3. CUT curves from habitat time series (source: Capra et al., 1995)

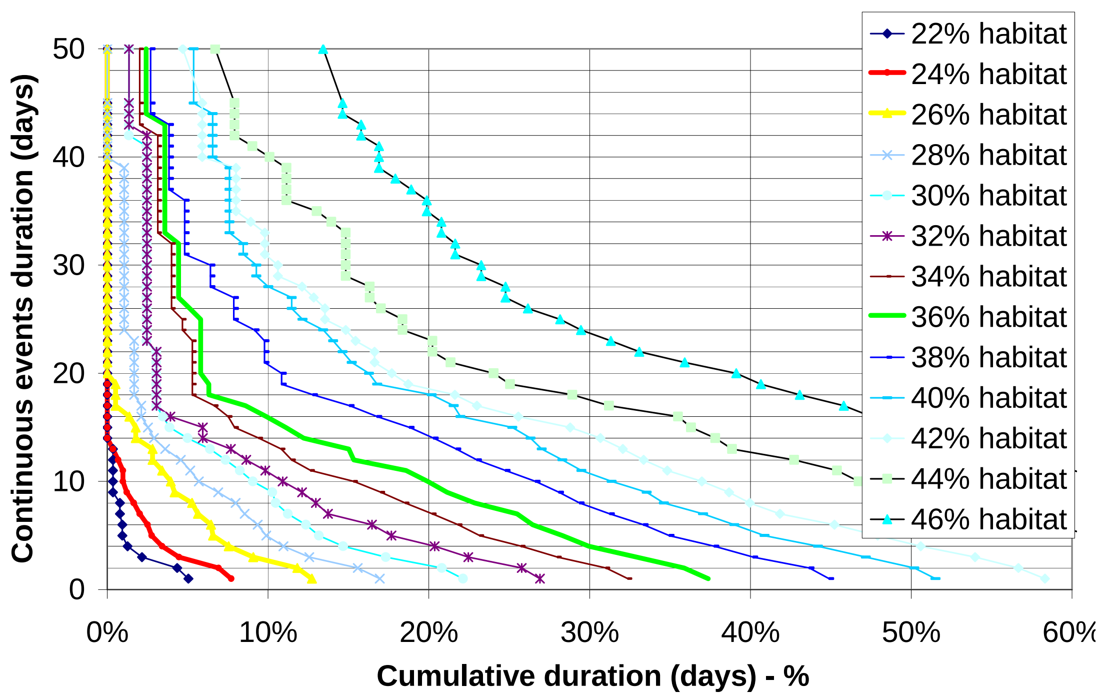


Figure 3.4. Continuous Under Threshold duration (CUT) curves for adult resident fish in the Quinebaug River during the summer season

additional mitigation actions in order to recover the fauna. In an operational sense, approaching catastrophic event duration should trigger an immediate pulse release.

The result of this analysis will be recommendations for seasonal habitat regimes consisting of allowable habitat quantity together with duration and frequencies of flow events with habitat under specific thresholds. In addition, the amount of water necessary to fulfill the above criteria will be defined for every season. We will develop a concept for the application of these criteria by introducing dynamic flow management rules. This will include flows that trigger protective actions, allowable durations of these flows, together with duration and magnitude of protective flow pulses.

In subsequent steps, we will list river channel improvement opportunities by identifying areas where such measures could be more easily applied than on private property (e.g. public parks). The potential of these measures can be analyzed by simulation of the gain in fish habitat. This step will assist in the evaluation of potential water management vs. restoration trade-off options in the water management plan. This may be particularly applicable where water use conflicts cannot easily be mitigated. The water management plan will build upon simulation results and determine how water can be allocated in order to satisfy the above flow recommendations.

Proposed Time Line and Data Collection Tasks:

Assuming we begin on August 16, 2004, we will conduct the following field tasks:

1. Mesohabitat Survey of Representative sites (8/16 – 9/1)
   - This survey will be conducted in depth, collecting PISF data on representative sites on the Souhegan River. The sites were outlined during the June survey of the entire river.
2. Scuba- survey of impoundments.
   - Scuba diving of impoundments, which were not originally surveyed in June, 2004.
3. Underwater survey of fish distribution.
   - Fish observations, which can be included with historical fish data.
   - Fish collections and identification using electrofishing or other gear.
4. Mussel and invertebrate survey.
   - This survey will entail sampling from given areas within representative sites to determine their presence, and to create a model from the results.
5. Second and third Mesohabitat survey. (September-October)
   - This survey will be conducted to acquire multiple river flow stages, which create a more thorough model for the river.

The exact dates cannot be determined at this time, but the September-October sampling events will correspond to flows in the middle and at the upper end of the 0.l15 – 2 cfsm range.

3.1.5 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Fish

The river is habitat for the endangered Banded Sunfish (Enneacanthus obesus). This fish occurs in slow-water areas and impoundments and prefers heavily vegetated areas (Cairns 2004). Two other species are considered endangered in New Hampshire, though they have not been identified in the area of the Souhegan River. These two species of fish are the Sunapee trout (*Salvelinus alpinus)* and the Shortnose sturgeon (*Acipenser brevirostrum)*. The Shortnose sturgeon is federally listed as endangered, in addition to being listed in New Hampshire. (New Hampshire Fish and Game Department) We will use the same technique as described above to determine the habitat for RTE.

Wildlife

Fowlers Toad

Historical records of the rare Fowler's Toad (*Bufo fowleri*) include several locations along the Milford to Merrimack reach of the Souhegan River, and although this species was not observed during the field investigation, suitable habitat is certainly present. This species prefers sandy outwash soils. As with the common American Toad (*Bufo a. americanus*), which was observed, Fowler's Toads are water dependent for breeding, eggs, and larval stage, and would likely use the same shallow, still margins of the Souhegan River in which American Toad tadpoles were observed, although breeding in other water bodies is also possible. Reduction in flows that expose the shallow river margins, backwaters and oxbows during larval development may strand and eliminate cohorts of toad tadpoles. Fowlers Toad breeds from late May to August, about one month later than American Toads, with tadpoles transforming in midsummer (Degraaf and Yamasaki 2000).

The method for evaluating habitat for Fowlers toad is the Floodplain Transect Model, provided in more detail under emergent wetlands below. In addition to the metrics developed for the emergent wetlands, the determination of minimum flow requirements for the Fowler's Toad will include:

- topographic cross sections of river channel along transects at previously mapped historical Fowler Toad habitats;
- identification of flows required to flood shallow margins and backwater areas within river banks (but beyond the main deep channel of the river) through mid-August.

Pied-Billed Grebe

The State-endangered Pied-Billed Grebe (*Podolymbus podiceps*) was reported from the Amherst Country Club. This species was not observed during the field visit June 28-30, 2004. Preferred habitat is densely vegetated emergent and deep marsh interspersed with open water that is more than 12 acres in size ((Degraaf and Yamasaki 2000; Banner 1998). To the extent that such a marsh is dependent on river flow, this marsh bird species would be flow dependent. A preliminary inspection of aerial photos of the Souhegan River floodplain indicates that there are several marshes that could be habitat for the Pied-billed Grebe, and some of these have a direct connection to the Souhegan River.

The evaluation of flow-dependency for the Pied-billed Grebe is similar to that for Floodplains and Emergent Wetlands so the procedure detailed for emergent wetland will be used to evaluate this species. Specific needs of the Pied-billed Grebe are that standing water must always be present.

Wood Turtle

The Wood Turtle (*Clemmys insculpta*) is a rare species that was observed basking on a log in the reach between Milford and Merrimack. This turtle overwinters on the bottoms of streams and feeds both on land and in the water (Taylor 1993) eating aquatic and upland plants and animals. This mobile, semi-aquatic species is not likely to be directly harmed by seasonal low flow reductions. However, this species is reported to be intolerant of pollution (DeGraaf and Yamasaki 2000), and therefore also indirectly flow dependent. Wood Turtles could also be harmed by a major decrease in winter water levels that could expose a hibernating turtle to freezing conditions (an event that would be of concern to many other IPUOCRS). The flow regime proposed under the WMP will be examined to insure that fall and winter water flows and fluctuations are protective of hibernating turtles. The likely overwintering habitat will be examined during the low flow and winterhabitat transect surveys, and the minimum flows sufficient to keep those areas inundated will be determined.

Osprey

The Osprey (*Pandion haliaetus*) is a State-threatened bird-of-prey observed foraging over the fish hatchery in Milford and over the river during the field survey, and reported from the Amherst Country Club. The closest known osprey nest in New Hampshire to the hatchery is at Lake Massabesic in Auburn/Manchester (NH Fish & Game wesbsite), which is well beyond the approximate 7 mile maximum foraging range reported for ospreys (Vana-Miller 1987). Ospreys observed along the Souhegan River in summer could be transient individuals. Ospreys consume primarily fish from clear, unobstructed water bodies. They dive up to 3 feet into the water, and so are most likely to feed in the pools and reservoirs, not shallow riffle areas. Only changes in flow that eliminate pools, reduce fish abundance, increase turbidity, or increase aquatic plant cover are likely to affect Ospreys. Flows that are protective of a healthy fish community will be protective of this species.

Common Loon

The Common Loon (*Gavia immer*) was reported from the Amherst Country Club, although it is unlikely to be nesting along the river. This State–threatened bird could be using river seasonally to forage for fish, its primary food. The Souhegan River is not likely to be a primary habitat for the Common Loon, but foraging opportunities for loons would be indirectly affected by changes in flow as for the Osprey. Like the Osprey, flows that are protective of a healthy fish community will be protective of this species.

Vegetation

Long's Bitter Cress

Long's bitter cress (*Cardamine longii* Fern.) is an obligate aquatic plant that has only been recorded from one location in NH (Greenville) and this was prior to 1984. It was not observed during the IPUOCR survey conducted by the field team on June 28-30, 2004. It is listed as a New Hampshire-Threatened plant, State rank is H (historical), and has Global Rank 3 (either very rare and local throughout its range or found locally in a restricted range, or vulnerable to extinction because of other factors). This plant is reported from tidal banks, usually shaded, mostly coastal (Crow and Hellquist 2000). In Maine it is estuarine (tidal wetland (non-forested, wetland)) and grows on sandy muck and cobbles (Maine Dept. of Conservation Natural Areas Program Fact Sheet, Long's Bitter Cress). In Bowdoinham, Maine it occurs on tidal banks and muck-covered ledges shaded by northern white cedar and yellow birch and experiences inundation twice daily (Crow 1982). There may be some taxonomic confusion associated with this plant. If present in the project area, it is likely to be flow dependent. Maintenance of a healthy natural community of aquatic plants will likely benefit this plant.

More information is needed prior to determination of assessment methods for flow requirements for this species. The presence of this plant in the designated reach should be confirmed prior to further evaluation.

Wild Garlic

Wild Garlic (*Allium canadense*) is a Faculative Upland plant on the State-Threatened List in NH with a State Rank of 1 (imperiled because rarity (generally less than six occurrences) or other factors demonstrably make it very vulnerable to extinction).

An historical record exists for the Town of Merrimack, but the location is unknown and may not be within Souhegan watershed. In Maine, the habitat for this species is described as usually found in rich, wooded bottomland hardwoods, in alluvial soils near streams (Maine Department of Conservation, Natural Heritage Program Biological and Conservation Database 2004). Magee and Ahles (1999) describe its habitat in New England as low wet woods and thickets, and rich woods. Though little information was available about the habitat of wild garlic in Merrimack, its wetland status and habitat information suggest it occurs on the upper terraces of streams and rivers. These terraces are typically affected by infrequent flooding events (often 10-year storms or greater), and so may be somewhat dependent on periodic scouring for survival. It was therefore considered flow-dependent on higher flows. Study sites for other IPUOCR will be selected to overlap with these sites, where possible. Alternatives in the WMP which may affect high flows will discuss potential impacts to this IPUOCR.

Wild Senna

There are historical records of the State Endangered Wild Senna (*Cassia hebecarpa*) in three of the towns along the Souhegan River (Amherst, Merrimack, and Milford) as well as a more recent record from Amherst. Robin Warren of the Amherst Country Club reports that this plant does grow on the banks of the Souhegan River. The New England Wildflower Society reports that typical habitat for this species includes disturbed habitats (roadsides, fields, and edges of streams), often in damp or alluvial soils. The few colonies in Massachusetts are found in annual floodplains, meadows and roadsides (Clark 2000). Wild Senna is classified as a Facultative species in New England, which means it is equally likely to be found in uplands and wetlands. Colonies that are located on the river floodplain may be flow dependent to the extent that they are reliant on periodic disturbance (such as scouring) and moist soils, and could be adversely affected by prolonged flooding. The location of this plant colony will be verified in the field if possible and flow dependence will be assessed based on location relative to the channel and floodplain.

Natural/Ecological Communities

Emergent Wetlands

The floodplain of the Souhegan River includes floodplain forest and oxbows and backwater areas with emergent wetlands. Several such marshes were observed between the Amherst Country Club and Turkey Hill Road; another large marsh is located just upstream of the Dam in Merrimack, and there is another large wetland complex above the dam in Greenville. Emergent wetlands are seasonally flooded to permanently flooded. Prolonged changes in depth or duration of water levels during the growing season could cause vegetation stress and changes and/or affect habitat functions of these wetlands. Numerous small fish, Painted Turtles (Chrysemys p. picta), and Green Frogs (Rana clamitans melanota) were observed in these marshes. Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of any flow changes.

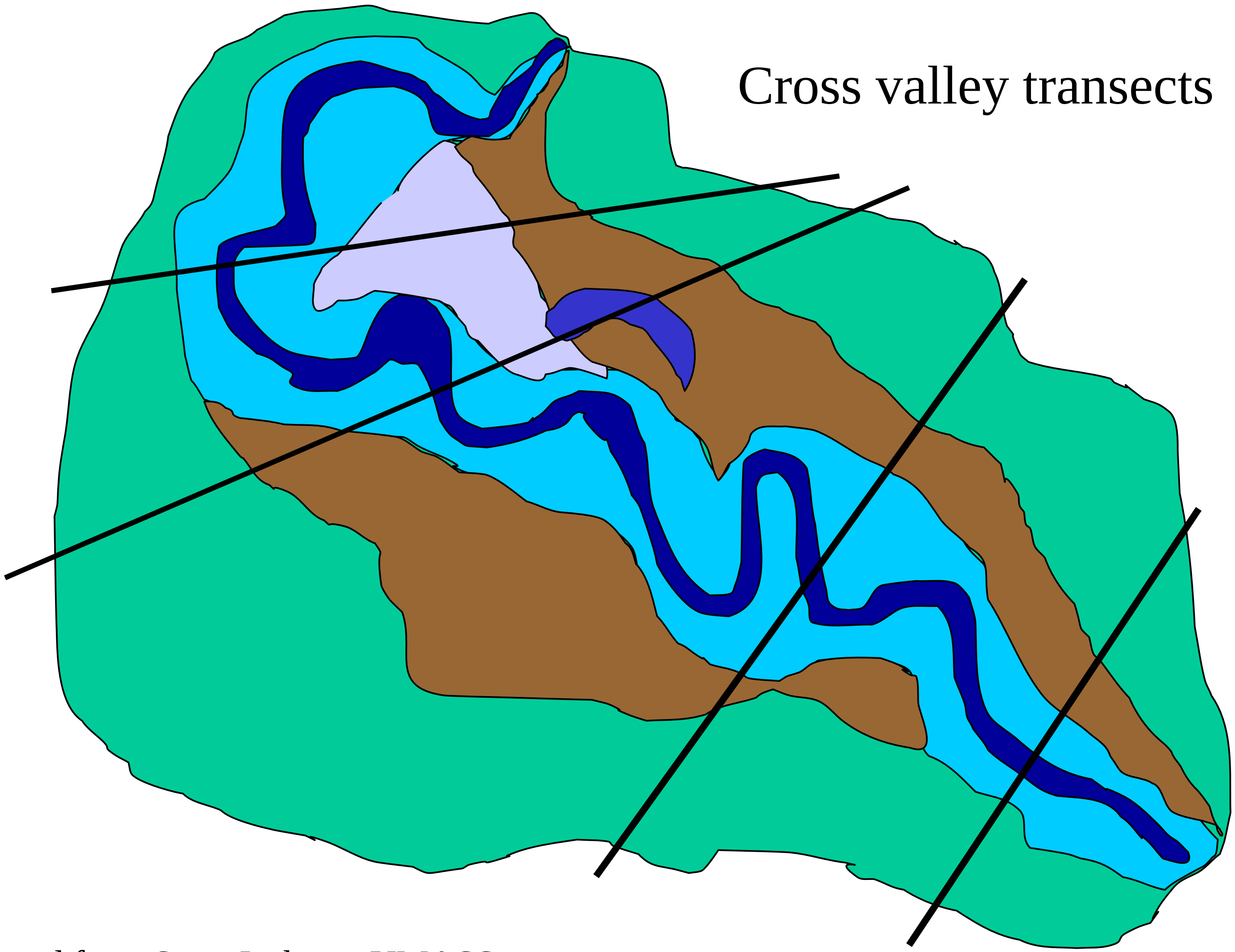
Determination of minimum flow requirements will involve transect surveys across the river floodplain and channel (the Floodplain Transect Model), with particular attention to emergent wetlands as described below:

- topographic survey of wetland and adjacent river channel along transects, including the lowest point of connection with the river channel and deepest point of marsh;
- elevation of water recorded simultaneously in wetland and river at seasonal low flow (or as determined by historical data), average and high flows. An attempt will be made to coordinate these evaluations with the evaluation of aquatic habitat and fauna.
- Use of a stage-discharge relationship and topography at each transect to determine profiles of water levels along each cross section at representative flows.
- primary vegetation types (emergent, floating leaved or submergent) in the wetland plotted along the transects;
- estimation of minimum flow required to maintain low flow surface water elevations of:
    - 0 (sediment surface) for emergents,
    - 6 inches for floating-leaved;
    - 12 inches for submergents.

This methodology will be applied at three or four sites in the designated reach. The number of necessary transects at each site will be determined in the field. These sites will be chosen to overlap with the range of flow dependent species wherever possible. Examples of the Floodplain Transect Model and type of output from this effort are presented in Figures 3.5 through 3.9.

Southern New England High-Energy Riverbank Community

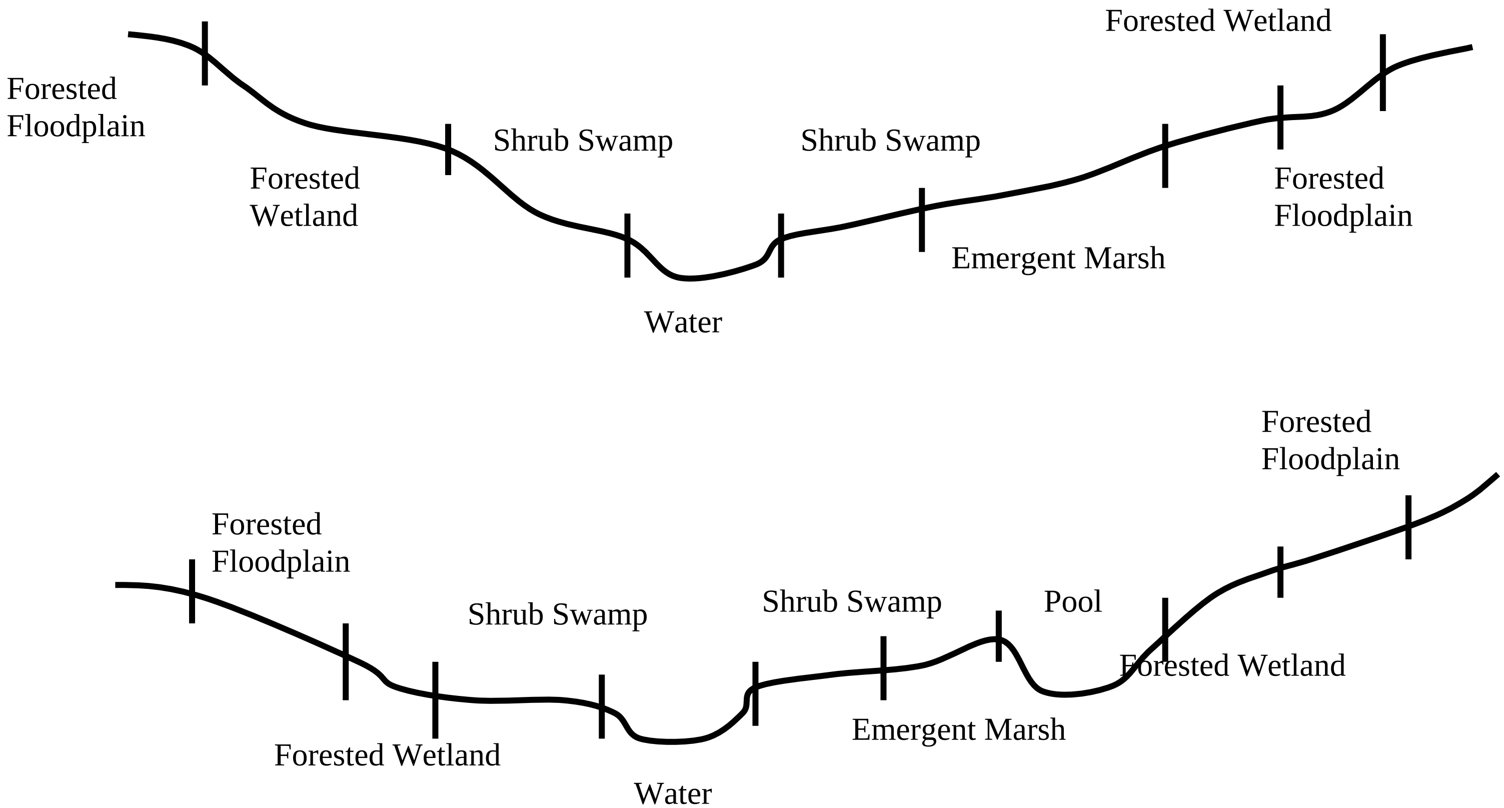
Sand and cobble bars with plant communities resembling the Southern New England High-Energy Riverbank Community (listed by New Hampshire Natural Heritage Inventory NNNHI) were observed in several locations along the Souhegan. Dominant species included twisted sedge (*Carex torta*), dogbanes (*Apocynum sibiricum; A. cannabinum*), Joe-pye weeds (*Eupatorium* ssp.), reed canary grass (*Phalaris arundinacea*), swamp candles (*Lysimachia terristris*), Willow (*Salix* spp.), and Grapes (*Vitis* sp.). At slightly higher elevations, shrubs such as silky dogwood (*Cornus amomum*) and alder (*Alnus incana*) along with several species of ferns and other herbaceous plants are often dominant. These habitats are dependent on periodic high flow scouring to reduce competition from plants less tolerant of flooding and coarse soils. The communities most dependent on scour are those at the lowest elevations in the channel. Prolonged absence of high seasonal or storm flows or ice scouring, or prolonged flooding during the growing season could adversely affect these communities. Reductions in seasonal low flows are unlikely to endanger these communities. Study sites for other IPUOCR will be selected to overlap with these sites, where possible. Alternatives in the WMP which may affect high flows will discuss potential impacts to this IPUOCR.



Adapted from Scott Jackson, UMASS

Figure 3.5 Layout of transects.

Transect #1

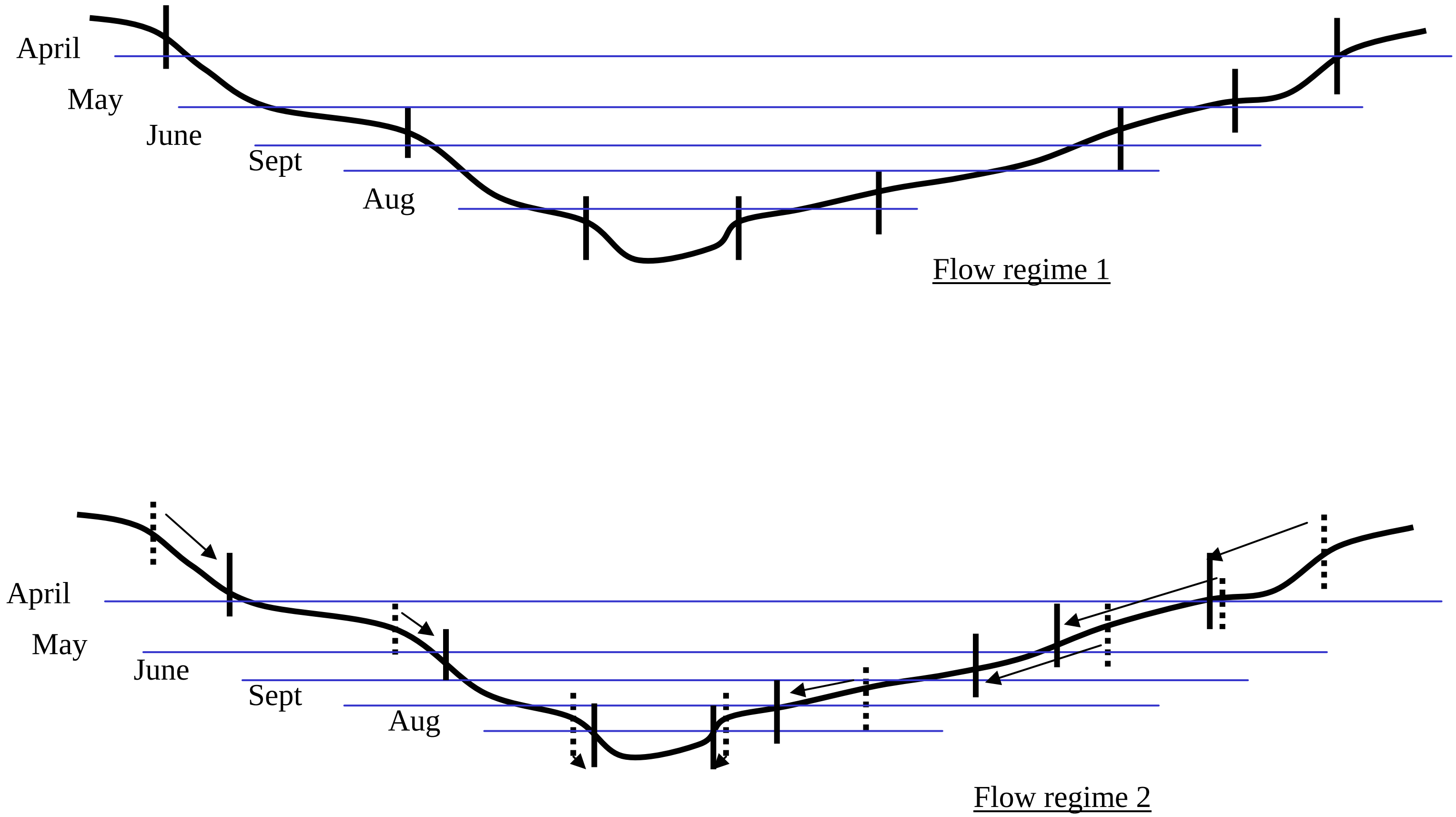


Transect #2

Adapted from Scott Jackson, UMASS

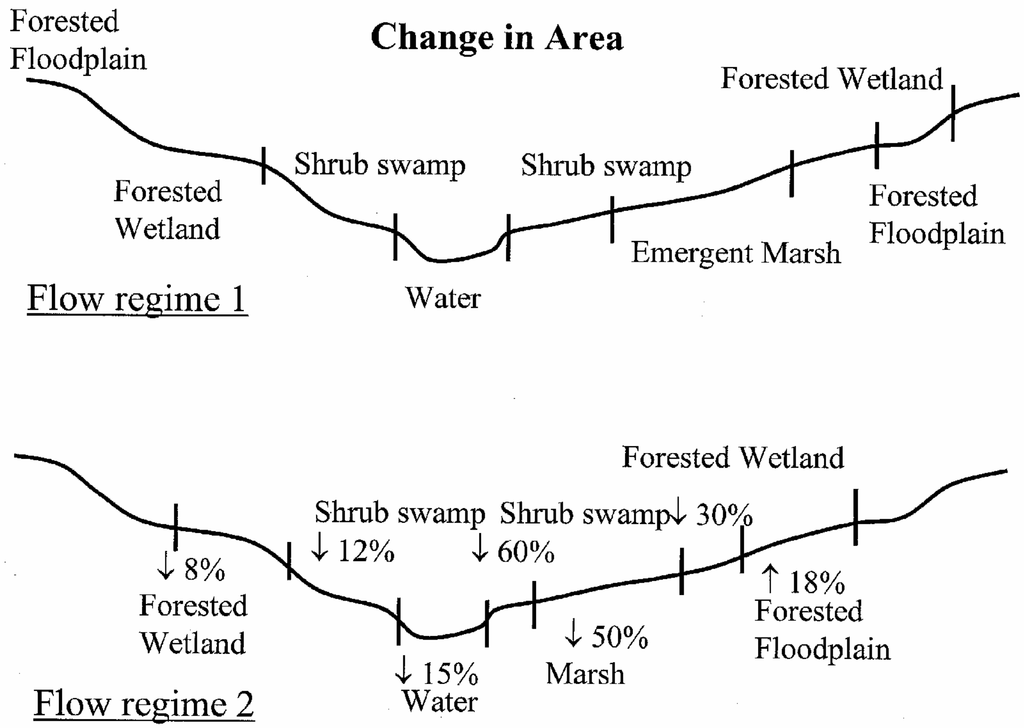
Figure 3.6 Transect habitat mapping.

Transect #1



Adapted from Scott Jackson, UMASS

Figure 3.7 Habitat under different flows.



Adapted from Scott Jackson, UMASS

Figure 3.8 Relative change between flow regimes.

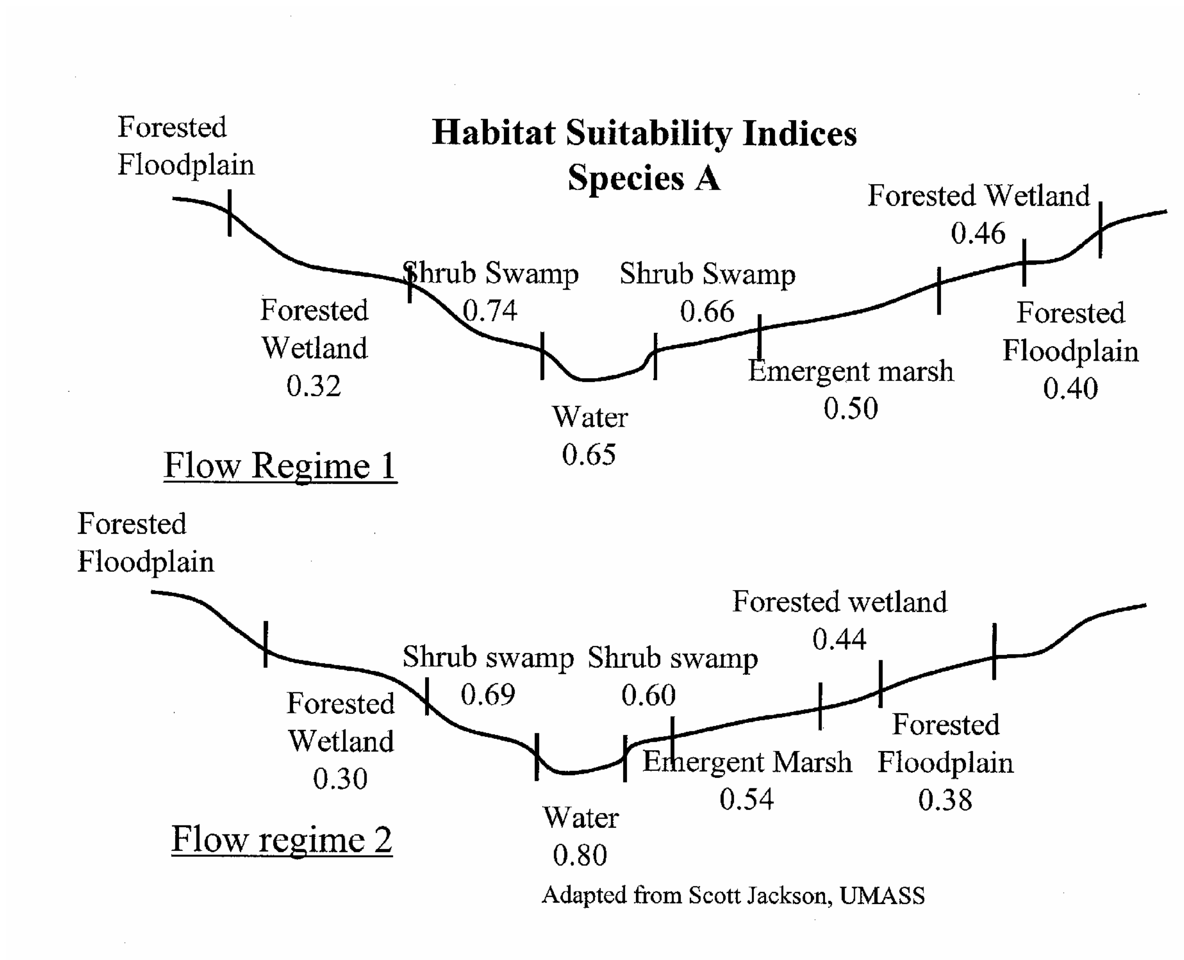


Figure 3.9 Habitat suitability under different flows.

Southern New England Floodplain Forest

Two Southern New England Floodplain Forest types were observed along the Souhegan River. Above the Town of Milford, floodplain forests were the Red Maple (*Acer rubrum*) Floodplain Forests typical of smaller rivers. Dominant plants observed also included Sycamore, White Ash, Ironwood, False Nettle, Ferns, Grapes, and Sedges. Within the Towns of Amherst and Merrimack, Silver Maple (*Acer saccharinum*) Floodplain Forests typical of larger rivers in the state were observed. Floodplain forest plant communities are dependent on periodic flooding and scouring to provide nutrients and reduce competition from flood-intolerant plant species. These communities often have a mesic moisture regime during the rest of the growing season, and are less dependent on low flows than flood flows. As with the forested wetlands, flow dependency is low relative to other IPUOCR entities. Study sites for other IPUOCR, particularly emergent wetlands and others to be evaluated by the Floodplain Transect Model, will be selected to overlap with these sites, where possible. Alternatives in the WMP which may affect high flows will discuss potential impacts to this IPUOCR.

3.1.6 Public Water Supply

The Pennichuck Water Works (PWW) historically withdrew water for public supply from 1965-1984 and maintains the right to withdraw water in the future from the Souhegan Woods Water System. The sources of this water supply are two wells located off Amherst Road in Amherst. In addition, the Town of Milford operates supply wells in the Town of Amherst. The hydrogeologic investigation to be conducted as a part of Task 2 will result in a clearer delineation of the relationship between these wells and river flow: that is the ability of wells to induce recharge from the river. If these wells are substantially connected to the river and creating induced recharge, the influence of the operation of these wells on river flows and achieving instream flows will be examined further as part of the water management plan. Although low river flow may be associated with low groundwater levels and therefore possibly lower well yields, maintaining high river flows in order to support enhanced well yields is an extremely inefficient mechanism and management strategy, and therefore is not considered. The scope of the present study was clearly delineated to focus on large groundwater withdrawals within 500 ft of the Designated River. It is recognized that groundwater withdrawals and instream flows are watershed issues, and that a complete study would assess the effects and management strategies of all water uses within the Souhegan River watershed. The complexity of this issue and the uncertainty involved in predicting low flow periods lead to the limitation that only wells within 500 feet of the river be included in this instream flow study. During average to wet periods, all water users may be satisfied. During low flow times, there may be habitat stress. To relieve this habitat stress by reducing groundwater withdrawals must recognize that the groundwater-river flow connection has a delayed response to the reduction in groundwater withdrawals: the farther wells are from the river, the longer the delay, and possibly the inability of the reduced groundwater withdrawals to relieve habitat stress. Stakeholder-NHDES discussions, prior to the performance of this instream flow study, recognized the complexity and reality of the groundwater-river flow connection, and these discussions resulted in the 500 foot limit for large groundwater withdrawals. There are very few registered wells that do not fall within 500 feet of the Designated River or one of its tributaries. In the Souhegan WMPA, two registered water users are exempted from the process because they have no source or discharge within 500 feet of the Designated River or one of its tributaries.

3.1.7 Pollution Abatement

Point source discharges include: Greenville WWTF (wastewater), Souhegan Wood products (non-contact cooling waters), Hitchiner Manufacturing (non-contact cooling waters), Milford WWTF (wastewater), and Harcros Chemicals (non-contact cooling waters). Savage Well and Fletcher Paint Superfund sites are located in Milford, NH adjacent to the river and have historically indirectly discharged pollutants into the waterbody. What about the fish hatchery?

The project team will review wasteload allocations and permits as well as superfund reports and relate prescribed protective flows to the discharges. It is worth noting that stressed vegetation was not observed in the designated reach in the vicinity of any of the permitted discharges during the field reconnaissance survey.

3.1.8 Hydroelectric Energy Production

The river corridor currently contains seven hydroelectric facilities (Table 3.4).

Table 3.4 Hydroelectric Facilities in the Designated River

Hydroelectric Facility	Location
Waterloom Pond Dam	New Ipswich
Otis Dam	Greenville
Souhegan River III Dam	Greenville
Souhegan River	Greenville
Souhegan River III Dam	Wilton
Pine Valley Mill Dam	Wilton
Mclane Dam	Milford

Hydroelectric energy production is dependent on the river flow. However, energy production in a low flow environment is often uneconomical or technologically unfeasible. The flows in the Souhegan River are low for much of the summer and at other times during the year (such as February) likely precluding hydroelectric energy production. During average and high flow periods, energy production does occur. It is possible that some alternatives to be considered in the water management plan will change the frequency of occurrence or the magnitude of high and average flows and may change the available period of time suitable for energy production. These situations will be addressed in the water management plan. Information to be obtained through interviews with affected dam owners (ADO) is essential to fully understanding the relationship between flow and energy production at each of these facilities. If hydropower is not produced at low flows, then there is no instream flow method for hydropower. If there is energy production at low flows, then these facilities require that their instream flow needs be addressed. For any of these facilities producing power at low flows, the nature of this power production will first be identified (for example production for a few hours per day from stored water, and the remainder of the day re-filling that storage). At that point, the hydropower ISF will be integrated into the WMP. Ramping studies related to hydropower production will not be included as a part of this effort.

3.1.9 Environmental/Fish Habitat

River Morphology and Aquatic Habitat

From aerial photographs and visual observation of the river, the form of the river varies throughout its length. Characteristics such as oxbows and meanders can be determined from maps and photographs, while substrate, width, depth and other characteristics are to be viewed at the small scale. Flow has the ability to alter the morphology of the river.

The Souhegan River channel cuts through numerous ledges that define its morphological character. The morphological character of the Souhegan ranges from a high gradient, straightened third order stream to a low gradient meandering fourth order river.

The high gradient portion of the Souhegan is located upstream of the confluence with Stony Brook in Wilton, NH. This portion is approximately nine miles long and is representative of a third order stream. In this upstream portion (our sections 1-24), the average width is 5 to 15 meters and the river is characterized by a relatively shallow and fast flowing current.

Below the confluence with Stony Brook the river maintains a high gradient until our section 33. Further downstream, the Souhegan River is a low gradient for almost the entire length. It meanders through the landscape, dotted with oxbows and remnants of side arms. Nevertheless, the 5-9 ft banks are steep suggesting a possible entrenchment tendency that is controlled by sporadic bedrock ledges and large cobble rapids. There are clear signs of some municipal pollution on almost the entire length of the river up to the mouth. The reaches referenced in the next paragraphs may be found on the map in Figure 3.10. The data associated with every section are summarized in Table 3.4.

Reach 1

For approximately six miles at the uppermost length of the designated reach, the Souhegan River flows through forested areas and is therefore heavily shaded with large amounts of overhanging vegetation and noticeable woody debris. Only 8% of the length is impounded by a dam in Greenville. The substrate consists in majority of large cobble and bedrock, with low amounts of sand. For the three miles the Souhegan runs parallel to Route 31, the banks are sometimes stabilized by riprap and the morphology of short stretches has been altered. Within the river channel, there were discarded pieces of riprap, which alter the substrate and aquatic habitats.

During the survey flow of 0.5 cfsm, the hydraulic patterns consisted primarily of run, riffles and rapids. The substrate consisted of mostly large cobbles and bedrock, with only small amounts of sand. Below the Greenville Bridge the river widens a little, and about a half a mile downstream there are the first cascades of the river (our section 6) in the Greenville Gorge where remnants of a breached dam were found. Further downstream the rivers' first island habitats are found and more glide types of habitat.

Our section numbers 6 to 12 were selected as representative sites of this reach.

Reach 2

Below the bridge next to the Monadnock Springs bottled water company (our sections 17-22), the river flows into more of an open space, although the banks remain mostly forested. In the vicinity of our section 21 and 22, the river flows through the Horseshoe Gorge. In this reach, the habitat types change including more runs and glides than found upstream.

Reach 1 and 2 of the river appears to be suitable for cold water, fluvial specialist fish fauna and we would expect an abundance of brook trout, salmon, daces, American eels and potentially for fallfish.

Our sections 16 to 18 were selected as representative sites of this reach.

Reach 3

Beginning with our section 23 which is impounded, the Souhegan River provides a dramatic contrast to upstream sections in terms of human induced alteration. Directly above the confluence with Stony Brook (our section 24), in which the stream order increases to 4th order, the Souhegan River enters

Table 3.5. Reach Descriptor Data.

		Hydro-morphological Units (%)												Stream Characteristics								Left Bank Characteristics*						Right Bank Characteristics*			
	Section # (From Upstream to Downstream)	Rapid	Cascade	Fast Run	Run	Riffle	Ruffle	Glide	Backwater	Pool	Plunge Pool	Sidearm	Island	Boulders	Riprap	Overhanging Vegetation	Submerged Vegetation	Canopy Cover	Undercut Banks	Woody Debris	Shallow Margins	Land Use	Clay	Erosion	Invasive Plants	Stabilization	Irregular Shoreline	Use	Clay	Erosion	Invasive Plants
	1	10	0	0	30	60	0	0	5	0	0	0	0	1	0	2	1	2	1	2	1	Forested	0	0	1	1	0	Forested	0	0	1
	2	20	0	0	40	40	0	0	0	0	0	0	0	1	1	2	1	2	0	2	1	Forested	0	0	1	1	0	Forested	0	1	1
	3	10	0	0	40	50	0	0	5	0	0	0	0	1	1	2	1	2	1	1	1	Forested	0	0	1	1	0	Residential	0	0	1
	4	20	0	0	0	60	0	0	0	0	0	5	10	1	1	2	1	2	1	0	1	Forested	0	0	1	0	0	Forested	0	0	1
	5	30	0	0	0	40	0	0	0	20	0	0	10	2	1	2	1	2	1	2	1	Forested	0	0	1	0	0	Forested	0	0	1
	6	30	30	0	0	0	20	0	0	0	40	0	0	2	2	2	0	2	0	0	0	Forested	0	0	1	0	1	Forested	0	0	1
Reach 1	7	25	0	0	30	20	10	0	0	15	0	0	0	2	1	2	0	2	2	1	0	Forested	0	0	1	0	0	Forested	0	0	1
	8	25	0	0	0	40	0	0	5	25	0	0	5	2	0	1	0	1	1	0	0	Forested	0	0	1	0	0	Forested	0	0	1
	9	30	0	0	10	30	20	0	0	0	0	0	10	2	0	1	0	2	1	0	1	Forested	0	0	1	0	0	Road	0	0	1
	10	40	0	0	0	30	5	0	0	20	0	0	5	2	1	1	0	1	1	0	1	Road	0	0	1	1	0	Forested	0	0	1
	11	25	0	0	0	35	0	35	5	0	0	0	0	1	0	1	0	1	1	0	1	Forested	0	0	1	1	0	Forested	0	0	1
	12	20	0	0	0	50	0	20	0	10	0	0	5	1	0	1	0	1	1	0	1	Road	0	0	1	0	0	Forested	0	0	1
	13	0	0	0	0	60	0	20	0	10	0	0	10	1	1	1	0	1	1	0	1	Forested	0	0	1	0	0	Field	0	0	1
	14	15	0	0	0	50	10	0	0	5	0	0	10	2	0	0	0	2	0	2	1	Forested	0	0	1	0	0	Forested	0	0	1
	15	10	0	0	35	40	0	0	0	15	0	0	50	1	0	2	0	1	0	2	1	Forested	0	0	1	0	0	Forested	0	0	1
	16	0	0	0	40	30	0	20	5	0	0	10	0	1	1	1	0	1	0	0	1	Field	0	0	0	1	0	Forested	0	0	1
	17	10	0	0	0	20	60	5	0	0	0	5	0	2	0	2	0	2	1	1	2	Forested	0	0	0	0	0	Forested	0	1	0
Reach 2	18	5	0	0	0	20	5	70	0	0	0	0	0	1	0	1	0	1	0	0	2	Residential	0	0	0	0	0	Forested	0	0	0
	19	0	0	0	0	40	0	60	0	0	0	0	0	1	0	2	0	2	0	1	2	Forested	0	0	1	0	0	Forested	0	0	1
	20	10	0	0	25	0	10	15	0	0	0	0	60	1	2	1	0	1	0	1	1	Road	0	0	1	1	1	Forested	0	0	1
	21	40	0	0	20	0	30	0	0	40	0	0	40	2	0	1	0	1	0	0	0	Forested	0	0	1	0	0	Forested	0	0	1
	22	40	0	0	15	15	30	0	0	15	0	0	0	2	0	1	0	1	0	1	1	Forested	0	0	1	0	0	Forested	0	0	1
	23	0	0	0	70	0	0	30	0	0	0	0	0	1	0	1	0	1	0	1	0	Forested	0	0	1	0	0	Forested	0	0	1
Reach 3	24	40	0	0	0	30	0	30	0	0	0	0	0	2	2	1	0	0	0	1	0	Urbanized	0	0	0	1	1	Urbanized	0	0	0
	25	0	0	0	55	45	5	0	0	0	0	0	0	0	2	2	0	2	0	0	0	Forested	0	0	1	0	0	Road	0	0	1
	26	10	0	0	5	30	0	50	0	5	0	0	0	1	1	1	0	1	0	0	0	Forested	0	0	1	1	0	Road	0	0	1
	27	0	0	0	0	40	0	50	0	0	0	0	10	0	0	2	0	1	0	0	1	Field	0	0	1	0	0	Field	0	0	1
	28	0	0	0	0	20	0	50	10	0	0	10	0	0	0	2	0	2	1	1	1	Forested	0	0	1	0	0	Pasture	0	0	1
Reach 4	29	0	0	0	50	15	0	20	5	0	0	0	0	0	0	2	1	2	0	1	0	Forested	0	0	1	0	0	Field	0	0	1
	30	0	0	0	70	0	0	0	5	20	0	0	10	0	0	2	1	1	1	1	0	Field	0	0	1	0	0	Field	0	1	1
	31	0	0	0	0	60	0	30	0	10	0	0	0	0	0	2	0	2	0	2	2	Field	0	0	0	0	1	Urbanized	0	0	0
	32	0	0	0	40	0	0	35	5	10	0	0	0	1	1	1	0	1	0	1	0	Field	0	0	1	0	0	Urbanized	0	0	0
	33	0	0	0	100	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	Residential	0	1	1	0	0	Urbanized	0	1	1
Reach 5	34	50	0	0	20	0	20	5	5	0	0	0	0	2	2	1	0	0	0	1	1	Residential	0	1	0	0	0	Urbanized	0	0	0
	35	10	0	0	10	0	60	20	0	0	0	0	0	2	1	1	0	0	0	1	1	Forested	0	1	1	0	0	Residential	0	0	1
	36	0	0	0	55	0	0	40	5	0	0	0	0	0	0	1	1	1	1	1	0	Field	0	1	1	0	0	Forested	0	1	1
	37	0	0	0	40	60	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	Field	0	0	1	0	0	Forested	0	1	0
	38	0	0	0	75	10	0	5	0	15	0	0	0	0	0	0	0	1	0	1	0	Field	0	1	1	0	0	Forested	0	1	1
	39	10	0	0	90	0	0	0	5	0	0	0	0	2	2	1	0	0	0	0	0	Field	0	1	0	0	0	Road	0	0	0
	40	0	0	0	40	60	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	Field	0	0	1	0	0	Field	0	1	1
Reach 6	41	0	0	0	20	0	0	0	0	80	0	0	0	1	0	1	1	0	0	1	1	Field	0	1	1	0	0	Field	0	1	1
	42	0	0	0	50	10	0	40	0	0	0	0	0	0	0	1	2	1	1	1	1	Field	0	0	1	1	0	Forested	0	0	1
	43	0	0	0	50	0	0	10	0	40	0	0	0	0	1	1	1	1	1	1	1	Field	0	0	1	0	0	Field	0	0	0
	44	0	0	0	45	15	0	50	0	40	0	0	0	1	1	1	1	1	1	1	1	Forested	0	1	1	0	1	Field	0	1	1
	45	5	0	0	40	15	0	0	0	40	0	0	0	1	0	1	1	2	1	2	0	Forested	0	1	0	0	1	Field	0	1	1
	46	0	0	0	60	0	10	5	0	25	0	0	0	1	1	1	1	0	0	1	1	Field	0	1	0	0	0	Forested	0	1	1
	47	0	0	0	30	0	0	20	0	50	0	0	0	0	1	1	1	1	1	1	1	Field	0	1	1	0	0	Field	0	1	-
	48	0	0	0	40	20	0	0	0	40	0	0	0	0	0	1	2	2	1	2	2	Forested	0	1	-	0	0	Forested	0	1	-
	49	0	0	0	40	10	10	0	0	40	0	0	0	1	0	1	0	1	2	2	1	Forested	0	1	-	0	1	Field	0	1	-
Reach 7	50	0	0	0	0	0	0	0	0	100	0	0	0	0	1	1	0	0	1	1	0	Forested	0	0	-	1	0	Forested	0	1	-
	51	0	0	0	50	10	0	40	0	0	0	0	0	0	1	0	1	1	0	2	1	Forested	0	1	-	0	0	Forested	0	1	-
	52	0	0	0	10	10	0	30	0	50	0	0	0	1	0	1	0	2	1	2	2	Field	0	1	-	0	0	Forested	0	0	-
	53	0	0	0	10	0	0	40	20	10	0	0	0	0	0	1	1	1	1	2	2	Residential	0	1	-	0	1	Forested	0	1	-
	54	0	0	0	20	10	0	50	0	20	0	0	0	2	1	0	1	1	0	2	1	Residential	0	1	-	0	1	Residential	0	1	-
	55	0	0	0	10	0	0	90	0	0	0	0	0	2	0	1	2	1	1	2	2	Forested	0	0	-	0	1	Forested	0	0	-
	56	60	0	0	10	0	20	0	0	10	0	0	0	2	0	0	0	1	0	0	0	Field	0	0	-	0	1	Residential	0	0	-
	57	0	50	0	30	0	0	0	0	20	0	0	0	2	0	0	0	0	1	0	1	Field	0	0	-	0	0	Residential	0	0	-
	58	0	0	0	20	60	0	30	0	0	0	0	0	0	0	0	2	1	1	2	2	Forested	0	1	-	0	0	Forested	0	1	-
	59	0	0	0	45	55	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	Forested	0	1	-	0	0	Forested	0	1	-
Reach 8	60	0	0	0	70	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	Forested	0	0	-	0	0	Forested	0	0	-
	61	0	0	0	20	0	0	0	0	80	0	0	0	0	0	1	1	1	1	2	1	Field	1	1	1	0	0	Forested	1	0	-
	62	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Forested	0	0	-	0	0	Forested	0	0	-
	63	0	0	0	25	0	0	25	0	50	0	0	0	0	0	0	0	0	0	0	0	Residential	0	0	-	0	0	Residential	0	0	-
	64	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Forested	0	0	-	0	0	Forested	0	0	-
	65	0	0	0	40	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	Field	0	1	-	0	0	Forested	0	0	-
	66	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	2	0	Forested	0	0	-	0	0	Forested	0	0	-
	67	15	75	0	0	0	0	0	0	0	0	10	0	2	0	0	0	0	0	2	0	Forested	0	0	-	0	0	Forested	0	0	-
	68	85	0	0	0	0	15	0	0	0	0	0	0	1	0	1	0	0	0	1	0	Forested	0	0	-	0	0	Forested	0	0	-
Reach 9	69	60	0	30	0	0	40	0	0	0	0	0	20	2	0	1	0	0	0	1	1	Forested	0	0	-	0	0	Residential	0	0	-
	70	10	0	0	70	20	0	10	0	0	0	0	0	1	0	1	0	0	0	1	1	Forested	0	1	-	0	0	Residential	0	1	-
	71	35	10	30	0	0	30	0	0	0	0	0	0	2	2	1	0	1	0	1	1	Forested	0	0	-	1	0	Forested	0	0	-
	72	50	0	0	0	50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Urbanized	0	0	-	0	0	Urbanized	0	0	-
	73	0	0	0	30	0	0	50	0	20	0	0	0	0	1	0	0	0	0	0	0	Urbanized	0	1	-	1	0	Urbanized	0	1	-

*Legend: 0 not present; 1 present; 2 abundant

Table 3.5 (Continued)

Reach	Section # (From Upstream to Downstream)	Right Bank Characteristics* Stabilization	Right Bank Characteristics* Irregular Shoreline	Substrate (%) Detritus (Organic Matter)	Substrate (%) Silt, clay, loam, sludge (Pelal)	Substrate (%) Sand (Psammal)	Substrate (%) Fine Gravel (<2 cm)(akal)	Substrate (%) Micro-lithal (2-6 cm, Birds egg - small fist)	Substrate (%) Meso-lithal (6-20cm, fist - hand size)	Substrate (%) Macro-lithal (20-40cm, hand - head size)	Substrate (%) Mega-lithal (>40cm, large boulders)	Substrate (%) Giga-lithal (Bedrock)	Substrate (%) Branches, roots	Gradient* Low	Gradient* Medium	Gradient* High	Temperature (F)	Entrenched*	Embedded*	Channel Width (m)	Depth (%) Shallow	Depth (%) Medium	Depth (%) Deep	Velocity (%) Slow	Velocity (%) Medium	Velocity (%) Fast
Reach 1	1	0	0	0	0	10	0	30	30	0	0	0	0	0	1	0	0	0	1	5	45	50	5	50	50	0
	2	0	0	0	0	40	0	30	30	0	0	0	0	0	1	0	0	0	1	5	60	35	5	40	60	0
	3	1	0	0	0	20	0	40	40	0	0	0	0	0	1	0	0	0	1	5	70	30	0	35	60	5
	4	0	0	0	0	0	20	30	50	0	0	0	0	0	1	0	64	0	1	5	80	20	0	20	70	5
	5	0	0	0	0	0	0	0	20	50	30	0	0	0	0	1	66	0	1	5	75	20	5	20	70	10
	6	1	1	0	0	0	0	0	0	5	20	75	0	0	0	1	67	1	0	5	10	50	40	15	45	40
	7	1	0	0	0	30	0	0	0	40	30	0	0	0	1	0	67	0	1	8	40	50	10	45	45	10
	8	1	0	0	0	0	15	0	15	60	0	0	0	0	1	0	67	0	1	5	25	50	25	25	60	15
	9	1	0	0	0	0	0	0	0	50	30	20	0	0	0	1	69	0	1	10	20	70	10	30	50	20
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	68	0	1	5	60	30	10	20	50	30
	11	0	0	0	0	0	10	0	30	60	0	0	0	0	1	0	0	0	1	8	70	20	5	30	60	10
	12	0	0	0	0	0	10	0	60	30	0	0	0	0	1	0	0	0	1	10	50	40	10	20	60	20
	13	0	0	0	0	0	0	20	50	30	0	0	0	0	1	0	0	0	1	10	70	20	5	60	35	5
	14	0	0	0	0	0	0	0	0	50	20	30	0	0	1	0	0	0	1	5	85	15	0	80	15	5
	15	0	0	0	0	0	0	0	20	60	20	0	0	0	1	0	0	0	1	10	70	20	10	40	55	5
Reach 2	16	0	0	0	0	0	0	60	40	0	0	0	0	0	1	0	63.5	1	1	15	40	40	20	90	10	0
	17	0	0	0	0	0	0	0	20	70	10	0	0	0	0	1	62	1	1	15	60	30	10	20	50	30
	18	0	0	0	0	0	0	0	40	50	20	0	0	0	1	0	64.5	1	1	15	60	35	5	40	50	10
	19	0	0	0	0	0	0	50	35	0	25	0	0	0	1	0	62	0	1	10	70	25	5	35	60	5
	20	1	1	0	0	50	0	30	20	0	0	0	0	0	1	0	64	1	1	15	80	20	0	35	60	5
	21	0	0	0	0	0	0	0	10	60	30	0	0	0	0	1	66	0	1	10	40	40	20	40	40	20
	22	0	0	0	0	0	0	0	0	50	35	25	0	0	0	1	67.5	1	0	15	20	60	20	20	50	30
Reach 3	23	0	0	0	0	0	0	40	60	0	0	0	0	0	1	0	68	1	1	15	60	35	5	65	30	5
	24	1	1	0	0	0	0	0	20	50	30	0	0	0	1	0	66	1	1	15	40	50	10	30	60	10
	25	1	0	0	0	0	0	10	40	50	0	0	0	0	1	0	64	1	1	12	20	75	5	20	50	30
	26	1	0	0	0	0	10	20	70	0	0	0	0	0	1	0	65	1	1	15	70	25	5	60	30	10
	27	0	0	0	0	0	0	40	50	10	0	0	0	0	1	0	69	0	1	10	85	10	5	80	20	0
Reach 4	28	0	0	0	0	0	0	50	10	40	0	0	0	0	1	0	70	1	1	20	20	60	20	70	30	0
	29	0	0	0	20	20	40	0	0	0	0	0	0	1	0	0	71	1	1	20	35	60	5	75	25	0
	30	0	0	40	30	20	0	0	0	0	0	0	0	1	0	0	72	1	1	15	45	45	10	80	20	0
	31	0	0	0	0	0	40	30	10	0	0	0	0	0	1	0	69	1	1	10	25	70	5	60	40	0
	32	1	0	0	0	20	0	25	40	0	0	0	0	0	1	0	67	1	1	15	40	45	15	95	5	0
Reach 5	33	1	0	60	0	30	10	0	0	0	0	0	0	1	0	0	62	1	1	20	20	50	30	90	10	0
	34	1	0	0	0	0	0	0	10	50	30	0	0	0	0	1	64	1	1	10	75	25	0	70	30	0
	35	1	0	0	0	0	0	0	0	60	20	10	0	0	0	1	64	1	0	20	45	50	5	80	20	0
Reach 6	36	0	0	20	0	40	0	40	0	0	0	0	0	1	0	0	65	1	1	20	20	65	15	85	15	0
	37	0	0	0	0	40	0	60	0	0	0	0	0	0	0	0	68	1	1	10	70	25	5	55	45	0
	38	0	0	0	10	70	0	30	0	0	0	0	0	1	0	0	64	1	1	15	40	55	5	90	10	0
	39	1	0	0	0	0	60	40	0	0	0	0	0	1	0	0	64	1	1	15	5	75	20	100	0	0
	40	0	0	0	0	0	40	60	0	0	0	0	0	0	1	0	62	1	1	15	10	75	15	60	40	0
	41	0	0	5	25	70	0	0	0	0	0	0	0	1	0	0	63	1	1	10	15	60	25	90	10	0
	42	1	0	0	0	30	30	40	0	0	0	0	0	0	1	0	64	1	1	10	45	55	0	65	35	0
	43	0	1	0	0	70	20	10	0	0	0	0	0	1	0	0	0	1	0	30	10	50	40	40	60	0
	44	1	1	0	0	80	10	0	0	0	10	0	0	0	0	0	0	1	0	30	20	40	40	10	90	0
	45	1	0	0	0	60	20	0	0	0	10	0	0	1	0	0	0	1	1	30	40	20	40	40	20	40
	46	1	0	0	80	0	10	0	0	0	0	0	10	0	1	0	0	1	1	30	45	40	15	25	60	15
	47	0	0	0	0	70	13	0	0	0	0	2	0	1	0	0	0	1	1	30	20	20	60	60	40	0
Reach 7	48	0	0	0	0	60	0	40	0	0	0	0	0	1	0	0	0	1	0	30	30	30	40	30	30	40
	49	0	0	0	0	75	5	0	0	0	0	0	20	0	0	0	0	1	0	20	30	30	40	30	30	40
	50	1	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	1	0	30	0	0	100	100	0	0
	51	0	0	0	0	80	20	0	0	0	0	0	0	0	0	0	0	1	0	30	40	60	0	80	20	0
	52	0	1	0	70	0	20	0	0	0	10	0	0	1	0	0	0	1	0	40	10	10	80	80	15	5
	53	0	1	0	0	80	20	0	0	0	0	0	0	1	0	0	0	1	0	35	40	20	40	95	5	0
	54	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	40	40	20	40	95	5	0
Reach 8	55	0	1	0	0	70	20	0	0	0	10	0	0	1	0	0	0	1	0	40	40	20	40	95	5	0
	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	40	80	20	0	0	30	70
	57	0	0	0	0	0	0	0	0	10	50	40	0	0	0	1	0	1	1	30	100	0	0	0	5	95
	58	0	0	0	50	0	20	30	0	0	0	0	0	0	1	0	0	1	0	30	0	50	50	0	90	10
	59	0	0	0	0	100	0	0	0	0	0	0	0	1	0	0	0	1	0	30	0	50	50	70	30	0
	60	0	0	0	0	100	0	0	0	0	0	0	0	1	0	0	0	1	0	30	30	45	25	70	30	0
	61	0	0	0	0	100	0	0	0	0	0	0	0	1	0	0	0	1	0	30	40	50	15	95	5	0
	62	0	0	0	0	80	20	0	0	0	0	0	0	1	0	0	0	0	0	0	20	30	50	100	0	0
	63	0	0	0	0	100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	30	70	0	20	30	50
	64	0	0	0	0	25	0	0	0	55	0	20	0	0	0	1	0	0	0	0	5	90	5	55	45	0
	65	0	0	0	0	0	0	0	0	0	100	0	0	1	0	0	0	0	0	0	40	50	10	100	0	0
	66	0	0	0	0	65	0	35	0	0	0	0	0	1	0	0	0	0	0	0	20	60	20	10	10	80
Reach 9	67	0	0	0	0	0	0	0	0	0	0	100	0	0	0	1	0	0	0	0	50	50	0	10	20	70
	68	0	0	0	0	0	0	0	0	80	0	20	0	0	0	1	0	1	0	25	10	70	20	10	60	30
	69	0	0	0	0	0	0	0	0	5	30	70	0	0	0	1	0	1	0	25	20	20	60	10	30	60
	70	0	0	0	0	0	0	0	0	5	15	75	0	1	0	0	0	1	0	20	5	60	35	50	35	15
	71	1	0	0	0	80	10	0	10	0	0	0	0	0	0	1	0	1	1	20	5	70	25	10	55	35
	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	60	10	10	30	60
	73	1	0	0	0	100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	20	60	20	80	20	0

*Legend: 0 not present; 1 present; 2 abundant urbanized areas with heavily stabilized banks. The confluence itself is created and enforced by old mill buildings and bridge crossings. Almost immediately after the confluence, two dams impound the river. Below the dams, the Souhegan River has been obviously realigned as a part of highway construction all the way down to our section 27. Twenty-five percent of the 3-mile length of Reach 3 is impounded.

In this reach the river still has a moderately high gradient yet substrate size reduces to more cobble, pebble, and gravel. The habitat type is dominated by glides and riffles. Consequently the boulder and woody debris cover is strongly reduced and banks are stabilized by riprap. Shallow margins (abundant upstream of this reach) are absent. Nevertheless, there is some overhanging vegetation and canopy cover shading.

In this area we would expect relatively poor habitats for the listed lotic species.

Our section 25 was selected as the representative site of this reach.

Reach 4

Beginning with our section 28 the river changes to a low gradient, wide (20 meter), meandering channel. This low gradient continues down to our section 32 and is accompanied by fields covered with remnants of oxbows and former side arms. This approximately 2.6 mile long reach has no dams. A number of tributaries join the river in this area.

The substrate changes very dramatically to a high abundance of sand and fines. The riverbanks become steep but covered with overhanging canopy that provides shading and a source of woody debris. The habitat types consist of run, pools, glides and riffles and it could be expected to support white sucker, daces and fallfish as well as variety of lentic fauna (eg. Sunfish). The presence of mussels and dragonflies were first observed in this section

Our sections 30 and 31 were selected as the representative sites of this reach.

Reach 5

Our section 33 crosses the town of Milford where the river is impounded by two dams over the length of approximately 1 mile. This 1-mile stretch makes up 60% of the total length of this reach. Downstream of the dam (our section 34 and 35), the river continues to flow through residential area and is high gradient. It cuts through bedrock ledge, which could be also expected under the impoundments.

The river banks in this area have an abundance of riprap as well as overhanging vegetation that does not provide much shading, but indicates the age of the construction. Some woody debris was also observed. Downstream of the impoundment the habitat consists of rapids, riffles, and runs with coarse but mixed substrate embedded in sand.

This reach can be expected to provide good habitat for variety of lotic species such as trout, salmon, fallfish, common shiner, daces, but also white sucker. Mussels and dragonflies were also observed in this section.

Our sections 34 and 35 were selected as the representative sites of this reach.

Reach 6

This is the first low gradient reach and it does not have any ledge structure and stretches until our section 47 (upstream of Boston Post Road Bridge). Almost the entire length of this approximately 3-mile reach is accompanied by a golf course that reduces canopy shading and woody debris. Meandering banks are active and if a forest were present the trees along these eroded banks may find their way into the river channel, increasing woody debris and dramatically changing river morphology. In the areas of bridges we observed heavy bank stabilization with riprap. The substrate is dominated by sand with the presence of submerged underwater vegetation. Hydraulic habitats consist of runs, pools, and glides accompanied by some low gradient riffles.

This reach should provide relatively good habitat for white sucker, fallfish and variety of lentic species. We observed large amounts of freshwater mussels (mostly eliptio) and dragonflies.

Our sections 36, 37 and 47 were selected as the representative sites of this reach.

Reach 7

Beginning with our section 48 the River meanders through more forested and residential areas where the abundance of woody debris and canopy shading increases. We also observed increases in shallow margins and the appearance of a few backwaters. Submerged underwater vegetation is less abundant. The banks are still high and eroded.

The hydraulic habitat consists of runs, pools, and glides accompanied by low gradient riffle associated with woody debris.

This reach should provide relatively good habitat for white sucker, common shiner, fallfish, and variety of lentic species. We observed large amounts of young of the year fish, freshwater mussels (mostly eliptio) and dragonflies.

Our sections 48 to 50 were selected as the representative sites of this reach.

Reach 8

Downstream of our section 54, the river turns into a mosaic of long, low gradient stretches interrupted by ledges and large rapids. The river meanders less than it does upstream and the oxbows are less abundant indicating steeper topography of a surrounding landscape. The riverbanks continue to be high and steep, and are covered with mature vegetation.

The 6 mile long reach has no impoundments but riverbanks are associated with residential use.

The dominating substrate continues to be sand with exception of bedrock in rapids areas. In the ledge and rapid areas the amount of woody debris is naturally lower. The river becomes over 30 meters wide such that canopy shading does not reach across its width. A large degree of shallow margins were observed on large sand banks in the middle of the river.

The hydraulic habitat is dominated by runs, riffles, pools, and glides accompanied by cascades and backwaters. This stretch of the Souhegan River can be expected to provide abundance and variety of habitat for fluvial and pond fish species. We observed large amounts of young of the year fish, freshwater mussels (mostly eliptio) and dragonflies.

Our sections 56, 57 and 61, 62 were selected as the representative sites of this reach.

Reach 9

Downstream of Wildcat Falls the river flows though the residential and urbanized town of Merrimack. The amount of cascades and ledges significantly increases (there are 3 cascades in this reach). Therefore the river has more moderate to high gradient character and does not meander. Of the approximately 2.5 mile length of this section, an inactive dam impounds 16% of the length. These impoundments create substantial wetlands.

The hydraulic habitat consists of runs, riffles, and cascades with abundance of boulders. Woody debris and shallow margins are present. At the bridge and residential areas the banks are stabilized with riprap. Substrate is a mixture of bedrock, cobble, gravel, sand and fines.

This reach is expected to provide habitat for a wide variety of species.

Our sections 67 to 71 were selected as the representative sites of this reach.

To assess river morphology we will apply a combination of hydro-morphological assessment (distribution of HMU's, depth velocity) with stream classification as described by Gallay et al 1973.

3.2 NON-FLOW DEPENDENT ENTITIES:

Non-flow dependent entities are defined as those entities which do not directly depend on a prescribed minimum flow for their existence or survival. In some instances, non-flow dependent entities are dependent on flow dependent entities (for example wildlife that feeds on fish); in this case, the prescribed minimum flow would be based on the fish. If flows are sufficient to support fish then the wildlife would be sufficiently protected. In other instances the IPUOCR is related to a water use but not completely dependent on it. For example, a golf course uses water for irrigation but will not close if sufficient water is not available. These IPUOCR are defined as non-flow dependent but will be addressed in the water management plan as water users.

3.2.1 Storage

There are 12 dams listed in the NHDES dams database on the designated reach (NHDES 2004):

Table 3.5. Listed Dams in the Designated River

Impoundment Name	Location
Souhegan River Dam	New Ipswich
Waterloom Pond Dam	New Ipswich
Otis Dam	Greenville
Souhegan River Dam	Wilton
Souhegan River III Dam	Greenville
Souhegan River	Greenville
Souhegan River III Dam	Wilton
Souhegan River Dam	Wilton
Pine Valley Mill Dam	Wilton
Goldman Dam	Milford
McLane dam	Milford
Merrimack Village Dam	Merrimack

All of the dams in the designated reach are operated essentially as run-of-the-river operations. There are no large impoundments within the designated reach therefore; the opportunities for large amounts of storage within the designated system do not exist. The impoundments are essentially full most of the time precluding the need for water to refill after drawdown. Some of the dams are considered affected dam owners (ADO's) for purposes of this study while others are not. Dams with impoundment areas of less than 10 acres are considered non-ADO dams. Ten dams on the designated reach fall in this category. The only two dams with impoundments greater than 10 acres are the Waterloom Pond Dam in New Ipswich and the Merrimack Village Dam in Merrimack. There are additional small impoundments throughout the watershed as well as several flood control structures near the headwaters of the Souhegan. Options for the management of river flows in the designated reach with water from all available storage will be included in the water management plan.

Surface water storage volume in reservoirs typically is reserved for one of three purposes: sedimentation, conservation, or flood control. The sediment storage is reserved for the sediment build-up over the life of the reservoir. Conservation storage is water that is released to meet needs (for example irrigation or hydropower) or maintained to meet needs (for example recreation). Flood storage is empty space intended to fill during flooding events. The objective for conservation storage is to be full all the time. The objective for flood control storage is to be empty all of the time. Per se, these types of storage themselves are therefore not flow dependant. The uses of the storage are flow dependant, and these uses are treated as their own separate IPUOCR categories. Therefore as an IPUOCR, storage is determined not to be flow dependant.

3.2.2 Recreation

Recreation resources in the vicinity of the designated reach include:

Golf: There are two public golf courses where the river crosses Route 122 in Amherst.

Other: Locations used for hiking, nature study, fishing access, picnicking and such include:

- The Taft Land owned by New Hampshire Fish and Game (NHF&G) in Greenville;
- The Town Forest owned by the Town of Wilton;
- Society for Protection of New Hampshire Forests (SPNHF) land in Wilton;
- The Souhegan River Scenic Easement owned by New Hampshire Department of Transportation (NHDOT) in Greenville/Wilton;
- The Horseshoe, a privately owned parcel in Wilton;
- The Milford Fish Hatchery, owned by NHF&G;
- Milford town land;
- Bicentennial Park, owned by the Town of Milford;
- Keyes field, owned by the Town of Milford;
- Emerson Park, owned by the Town of Milford;
- Kaley Park owned by the Town of Milford;

- Cemetery Fields on Merrimack Road near Beaver Brook (that feeds the Souhegan), in Amherst;
- Amherst canoe port, owned by the Town of Amherst;
- Route 122 access, owned by the Town of Amherst;
- The Sherburne Site, owned by the Town of Amherst;
- Eighty Acres, owned by the Town of Merrimack; and
- The Turkey Hill Bridge Site, owned by the Town of Merrimack.

The sites and activities listed above are not classified as flow dependent. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.3 Conservation/Open Space

Open Space parcels include the following:

- Merrimack: Eighty Acres site-predominately forested includes Wildcat falls, Turkey Hill bridge site-open and forested, provides car top access to the River, Davidson Avenue green space-predominately forested, and Whippoorwill Boy Scout Camp
- Amherst: Scott and Sherburne sites- predominately floodplain, The Currier Land- predominately floodplain, and The Curtis Well Site- public drinking water, mixed woods and fields.
- Milford: An unnamed piece east of downtown- floodplain, forest, field, the site east of the swinging bridge-open area and woods, Emerson Park- a small developed park, Keyes Memorial Park- floodplain, open recreational area, and an unnamed parcel adjacent to the fish hatchery- mixed fields and forest.
- Wilton: The Town Forest, SPNHF owns a parcel along the River- forested, NHDOT owns a 3.2-mile scenic easement on Rt. 31 in Wilton and Greenville.
- Greenville: NHF&G owns a large parcel that is predominately forested and includes the gorge.
- New Ipswich: There are a couple of small pieces of land owned by the town along the River that are predominately forested.

The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.4 Maintenance and Enhancement of Aquatic and Fish Life

Management of Exotic/Invasive Species

There are exotic and invasive species of vegetation and invertebrates present in New Hampshire, which have the potential for causing harm to the watershed. These species can be found listed on the New Hampshire Department of Environmental Services website. For the purposes of this project, these species are not IPUOCRs, although some are flow-dependent. Rather, these species are threats to an IPUOCR – namely the communities of native plants and their habitat value. Maintenance and protection of these natural communities (and control of invasives) is assumed to be facilitated under the Natural Flow Paradigm, which should favor the adapted native plants. But invasive species may be favored when deviations from the natural flow paradigm occur. The potential for increases in the species mentioned below will be evaluated during the Floodplain Transect/seasonal water level modeling.

The only aquatic invasive species found in a water body near the Souhegan River is Variable milfoil (*Myriophyllum heterophyllum*), which is very difficult to eradicate once it is established. This species was not observed in the river during the course of the study, and has not been evaluated further. It is unknown how this species responds to changes in river flow.

Several wetland and upland invasive species were observed during the field investigations, including Purple Loosestrife (*Lythrum salicaria*), a species that relies on water transport of seed to spread and germinates in seasonally exposed mudflats. This is a perennial species that increases in periods of low flow, and could become more abundant if low water conditions are prolonged. Japanese knotweed (*Polygonum cuspidatum*) is a persistent perennial that spreads rapidly by rhizomes, fragments of which are often transported by water. Though such transport is possible at any flow, it is most likely to occur at high flows. The wind dispersed seed rarely germinates. This plant was observed on the riverbank in some locations, and is likely to spread regardless of flow. Asiatic bittersweet (*Celastrus orbiculatus*), European buckthorn (*Frangula alnus*) and Autumn Olive (*Eleagnus umbellata*) were present in open upland floodplains, and are not considered flow dependent, though seed may be carried downstream. A flow regime that encourages a healthy native community of flora and fauna in the designated reach will discourage the spread of exotic/invasive species.

3.2.5 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Wildlife

Eastern Hognose Snake

The Eastern Hognose Snake (*Heterodon platyrhinos*) is a Threatened Species in New Hampshire found in sandy forests, fields and other openings (DeGraaf and Yamasaki 2000). Although Hognose Snakes may feed in riparian habitats, this species is not considered water dependent and therefore not flow dependent.

Grasshopper Sparrow

The Grasshopper Sparrow (*Ammodramus savannarum*) requires moderately open grasslands with patchy bare ground and some perches for singing (Degraaf and Yamasaki 2000). While such habitats may be present in the agricultural lands in the Souhegan River floodplain in Amherst and Merrimack (from which this species has been recorded), the bird itself is not dependent on the river, and is unlikely to use habitats with flooding during the growing season.

Vegetation

Giant Rhododendron

The Giant Rhododendron (*Rhododendron maximum*) is designated as a Facultative plant in this region, meaning it is equally likely to occur in wetlands and uplands. Giant rhododendron occurs on stream banks, pond margins, swamps, wet woods and moist uplands (Crow and Hellquist 2000). It grows in acidic and moist soils. In New Hampshire these sites are primarily found in basin swamps, along lower slopes, or alongside brooks and ponds. This species us usually found in shaded areas such as low-lying wooded areas of eastern hemlock, red spruce, oaks, red maple and beech (from NH Natural Heritage Program data base: Fact Sheet, Giant Rhododendron (*Rhododendron maximum* L.). One large NH population is located in Rhododendron State Reservation, Fitzwilliam, NH. This species is not currently listed in NH, but proposed for NH threatened status, with a State Rank of 2 (imperiled because rarity (generally six to 20 occurrences). Historically reported for the Towns of Greenville, Milford, and Wilton. Searches for this species in historically mapped locations were not successful in June and July 2004. Of the 15 known locations in NH, only six have been verified since 1980, and the Souhegan River population is not among them (from NH Natural Heritage Program data base: Fact Sheet, Giant Rhododendron (*Rhododendron maximum* L.), 2002). Giant Rhododendron is not particularly flood tolerant, and is therefore an unlikely component of the floodplain, and not a flow-dependent IPUOCR.

Siberian Chives

Siberian Chives (*Allium schoenoprasum* var. *sibiricum* (L.) Hartman is a facultative upland herb (Magee and Ahles 1999), meaning it is more likely to be found in uplands but tolerates wetland conditions, and is listed as Threatened in New Hampshire, State Rank 2 (imperiled because of rarity). Siberian chives is listed in New Hampshire and Minnesota as threatened, but listed as a noxious week in Arkansas. There are 7 historical records from the Town of Merrimack, but none reported in the last 20 years from the town. The preferred habitat is gravelly river shores and fields (Magee and Ahles 1999), which could include the Southern New England High-Energy Riverbank Community. Since this species is also adapted to fields, it does not appear to be flow dependent.

Birds Foot Violet

The Birds Foot Violet (*Viola pedatus var linearloba*) is a State Threatened plant Ranked 2 (imperiled because rarity (generally 6 to 20 occurrences) or other factors demonstrably make it very vulnerable to extinction. It was historically recorded (prior to 1984) from the Town of Merrimack, but the exact location is unknown and may not be within Souhegan watershed. It is not a recognized wetland plant, and a Minnesota web source describes it as occurring in upland sandy woods. Though no information was available about the habitat of birds foot aster in Merrimack, its wetland status and habitat information suggest it occurs in upland habitats and is unlikely to be affected by Souhegan river water levels.

Skydrop Aster

As with the Bird's Foot Violet, the Skydrop Aster (Aster patens var. patens) is a State-Threatened plant with little natural history or habitat information available. It was recorded for the Town of Merrimack but the exact location is unknown. All accounts indicate it occurs in dry woods and openings (Magee and Ahles 1999, Gleason and Cronquist 1963, and USDA Species-at-risk). Though no information was available about the habitat of skydrop aster in Merrimack, its wetland status and habitat information suggest it occurs in upland habitats and is unlikely to be affected by Souhegan river water levels.

Goat's Rue

Goat's Rue (*Tephrosia virginiana*) is listed as Endangered in New Hampshire, with a State Rank of 1 (imperiled because rarity (generally less than 6 occurrences) or other factors demonstrably make it very vulnerable to extinction). It was recorded from the Town of Merrimack prior to 1984, and again the location is unknown and may not be within Souhegan watershed. The USDA species-at-risk web site describes its habitat as well-drained soils in open oak and pine woods on ridges, sand prairies, sand dunes, roadsides, abandoned fields and other rural sites. Magee and Ahles (1999) describe its habitat in New England as open deciduous or pine woods and clearings, barrens, dunes and roadsides in sandy soil. This habitat information suggests that the plant occurs in upland habitats and is unlikely to be affected by Souhegan river water levels.

Stiff Tick Trefoil

The Stiff Tick Trefoil (*Desmodium rigidum*) is also designated as Endangered in New Hampshire, and was recorded historically (pre-1984) from Merrimack. (historical, recorded prior to 1984). No local information was found for this species, and it's location may not be within Souhegan watershed. Magee and Ahles (1999) and Gleason and Cronquist (1963) describe its habitat in New England as dry woods and thickets. Though no information was available about the habitat of stiff tick trefoil in Merrimack, its wetland status and habitat information suggest it occurs in upland habitats and is unlikely to be affected by Souhegan river water levels.

3.2.6 Water Quality Protection/Public Health

The river supports its water quality classification, class B, at all locations. According to the 1999 Souhegan River Nomination, certain sites exceeded acceptable limits for bacteria (below Wilton and at 122 bridge) and Phosphorous (Greenville and Milford wastewater treatment facilities and continued downstream). Low DO levels were also documented at the Pine Valley Mill site. The Souhegan River Watershed Report (1997) states "The Souhegan River, with one exception, met all of its water quality standards criteria during dry weather and demonstrated that it is fully supporting its Class B designation of being fishable and swimmable. However, the biotic integrity of the waterbody does show signs of impairment and degradation. Cold-water and pollutant intolerant non-game species were present in the Souhegan, indicating that chemical and physical water quality conditions are favorable to supporting a diverse cold and warm water fishery. While only one station was rated non-impacted, most supported healthy macroinvertebrate communities and fell into the slight impact range." Recent NHDES and Souhegan volunteer monitoring program water quality data will be reviewed to insure that this IPUOCR is still correctly classified as non-flow dependent.

3.2.7 Aesthetic Beauty/Scenic

These areas include: Route 31 along scenic Water Loom Pond and under High Bridge in the center of Town; in Greenville Route 31 affords views of pastures and agricultural lands and a scenic gorge; Route 31 proceeds through a 3.2 mile corridor protected by a scenic easement donated by the NHDOT; The Horseshoe in Wilton is an area where the River passes through a series of ledges that are steep on one side; in Milford the river passes under historic Green Bridge; The Souhegan River Trail in Milford follows the river along the state owned fish hatchery property and the adjacent Town owned property; in Merrimack are Indian Ledges and Wildcat Falls. There has never been a dry reading recorded throughout the record of flow for the gage above Wildcat Falls. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.8 Cultural/Community Significance

The river is discussed in each of the municipal master plans and is recognized as a significant community resource. The Souhegan River Watershed Association plays a key role in the protection and preservation of the river. The Souhegan River Watershed Report (1997), includes significant amounts of information about the river and provides specific recommendations for local and regional action. All communities in the watershed received the study well and some have started to implement the recommendations of the study. The study recommendations include amendments to local zoning ordinances and land use regulations, the development of a continuous trail along the River, additional public access sites in each community, public education on River resources and their protection, continuation of the volunteer monitoring program and state actions.

3.2.9 Historical or Archaeological

According to the New Hampshire Division of Historical Resources, New Hampshire Archaeological Inventory, there are four sites of historical significance within 100 meters of the Souhegan River along the designated reach. Three of these sites are located in Milford and one in Merrimack. Historical and archeological information is sensitive in nature therefore specific site locations are not identified in public documents.

Historical Resources located in the towns along the designated reach include the following:

Merrimack: McClure--Hilton House 16 Tinker Rd. Listed; 12-01-1989, Signer's House and Matthew Thornton Cemetery S of Merrimack on US 3 Listed; 12-22-1978 Amherst Village Historic District 101 and NH 122 Listed; 08-18-1982

Milford: Milford Cotton and Woolen Manufacturing Company 2 Bridge St. Listed; 08-18-1982,Milford Town House and Library Annex Nashua St. Listed; 12-01-1988, Peabody, William, House N.River Rd. Listed; 11-30-1979

Wilton: County Farm Bridge NW of Wilton on Old County Farm Rd. 05-14-1981. Cragin, Daniel, MillW of Wilton at Jct. of Davisville Rd. and Burton Hwy. Listed; 03-23-1982, Hamblet--Putnam--FryeHouse 293 Burton Hwy. Listed; 06-22-2000, Stonyfield Farm NW of Wilton on Foster Rd. Listed; 08-03-1983, Whiting, Oliver, Homestead Old County Farm Rd. Listed; 03-09-1982, Wilton Public and Gregg Free Library Forest St. Listed; 01-11-1982, Monument Park, a 1.0 acre park that is identified as a historic site for passive use.

New Ipswich: New Ipswich Center Village Historic District Roughly bounded by Turnpike Rd., Porter Hill Rd., Main St., NH 123A, Preston Hill, Manley and King Rds. Listed; 09-03-1991, New Ipswich Town Hall Main St. Listed; 12-13-1984.

3.2.10 Hydrological/Geological

Unique geologic formations

The river runs through a gorge in Greenville with steep sides. The Horseshoe in Wilton is another geologically significant area that serves as the local swimming hole. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of these formations.

Aquifers

The Milford-Souhegan aquifer consists of as much as 114 ft. thick of unconsolidated glacial sediments and has a maximum saturated thickness of approximately 100 ft. Horizontal hydraulic conductivity of stratified-drift deposits ranges from approximately 1 to 1,000 ft per day (Harte and Mack 1992). The groundwater flow is governed by the hydraulic connection between the Souhegan

River and its tributaries. In the western reaches of the Souhegan River, the River recharges the aquifer and groundwater flow is away from the river. In the eastern reaches ground water discharges into the river and groundwater flow is towards the river. Based on October 1998 stream flow data the aquifer is recharged from surface water infiltration at a rate of 1.44 ft3/s (Harte and Mack 1992). During extreme low-flow events, aquifer recharge from the river will be reduced. This may impact groundwater resources in the vicinity of the river. For this study, this IPUOCR is not considered to be flow dependent.

3.2.11 Agricultural

Abutting the river are parcels of land in Milford used as agricultural fields. Many of these fields are irrigated with water from the Souhegan. Agricultural uses of water will be addressed in the water management plan.

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